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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/900,992	07/09/2001	Naoya Hasegawa	9281-3995	6893

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EXAMINER	
MAGEE, CHRISTOPHER R	
ART UNIT	**PAPER NUMBER**
2653	

DATE MAILED: 03/11/2005

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)
	09/900,992	HASEGAWA ET AL.
	Examiner	**Art Unit**
	Christopher R. Magee	2653

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *02 November 2004*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-34* is/are pending in the application.

4a) Of the above claim(s) *17-34* is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-16* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on _____ is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☒ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date *9/7/04*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

DETAILED ACTION

Election/Restrictions

1. Applicant's election without traverse of Species A (Claims 1-16) in the reply filed on 11/02/2004 is acknowledged.

Priority

2. Receipt is acknowledged of papers submitted under 35 U.S.C. 119(a)-(d), which papers have been placed of record in the file.

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> *A person shall be entitled to a patent unless –*
>
> *(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.*

3. Claims 1, 2 and 9-16 are rejected under 35 U.S.C. 102(b) as being anticipated by Hasegawa et al. (hereinafter Hasegawa '647) (JPO English machine translation of JP 11-191647, publication date 7/13/1999).

- Regarding claims 1 and 12, Hasegawa '647 discloses an exchange coupling film comprising an antiferromagnetic layer [4] and a ferromagnetic layer [3], which are formed in contact with each other so that the magnetization direction of the ferromagnetic layer is pinned in a predetermined direction by an exchange coupling magnetic field produced at the interface

between both layers, wherein the antiferromagnetic layer is made of an antiferromagnetic material comprising an element X (at least one element selected from Pt, Pd, Ir, Rh, Ru, and Os) and Mn; [Hasegawa English translation, section 0017] and

in a section of the exchange coupling film in parallel with the thickness direction thereof, the crystal grain boundaries formed in the antiferromagnetic layer and the crystal grain boundaries formed in the ferromagnetic layer are discontinuous in at least a portion of the interface [Hasegawa English translation, section 0017].

- Regarding claim 2, Hasegawa '674 discloses the antiferromagnetic layer and the ferromagnetic layer, equivalent crystal planes represented by a (111) plane are preferentially oriented in parallel with the interface [Hasegawa English translation, sections 0019 to 0021].
- Regarding claim 9, Hasegawa '647 teaches the antiferromagnetic layer is made of a X-Mn-X' alloy (wherein X' represents at least one element selected from Ne, Ar, Kr, Xe, Be, B, C, N, Mg, Al, Si, P, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Ge, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the rare earth elements) [Hasegawa English translation, sections 0023 and 0024].
- Regarding claim 10, Hasegawa '647 teaches the X-Mn-X' alloy is an interstitial solid solution in which the element X' enters the interstices between space lattices composed of the element X and Mn. or a substitution solid solution in which the lattice points of crystal lattices composed of the element X and Mn are partially substituted by the element X' [Hasegawa English translation, sections 0023 and 0024].
- Regarding claim 11, Hasegawa '647 teaches the composition ratio of the element X or elements (X + X') is 45 at% to 60 at% [Hasegawa English translation, sections 00111 and 0112].

- Regarding claim 13, Hasegawa '647 discloses a magnetoresistive element comprising an antiferromagnetic layer [4], a pinned magnetic layer [3] formed in contact with the antiferromagnetic layer so that the magnetization direction is pinned by an exchange coupling magnetic field with the antiferromagnetic layer, a free magnetic layer [1]formed on the pinned magnetic layer with a nonmagnetic intermediate layer [2] provided there between, and a bias layer [5] for orienting the magnetization direction of the free magnetic layer in a direction crossing the magnetization direction of the pinned magnetic layer, wherein the antiferromagnetic layer and the pinned magnetic layer formed in contact with the antiferromagnetic layer comprise an exchange coupling film according to Claim 1 [Hasegawa English translation, section 0033, drawing 1].

- Regarding claim 14, Hasegawa '647 discloses a magnetoresistive element comprising an antiferromagnetic layer [4], a pinned magnetic layer [3] formed in contact with the antiferromagnetic layer so that the magnetization direction is pinned by an exchange coupling magnetic field with the antiferromagnetic layer, a free magnetic layer [1] formed on the pinned magnetic layer with a nonmagnetic intermediate layer [2] provided there between, and antiferromagnetic exchange bias layers [9] formed on or below the free magnetic layer with a space corresponding to a track width Tw, wherein the exchange bias layers and the free magnetic layer comprise an exchange coupling film according to Claim 1, and magnetization of the free magnetic layer is pinned in a predetermined direction [Hasegawa English translation, section 0034, drawing 2].

- Regarding claim 15, Hasegawa '647 discloses a magnetoresistive element comprising nonmagnetic layers laminated on and below a free magnetic layer [1], pinned magnetic layers [3]

located on one of the nonmagnetic intermediate layers [2] and below the other nonmagnetic intermediate layer, antiferromagnetic layers [4] located on one of the pinned magnetic layers and below the other pinned magnetic layer, for pinning the magnetization direction of each of the pinned magnetic layers in a predetermined direction by an exchange coupling magnetic field, and a bias layer [5] for orienting the magnetization direction of the free magnetic layer in a direction crossing the magnetization direction of the pinned magnetic layers, wherein the antiferromagnetic layers and the pinned respectively formed in contact with the antiferromagnetic layers comprise an exchange coupling film according to Claim 1 [Hasegawa English translation, section 0035, drawing 3].

- Regarding claim 16, Hasegawa '674 discloses a magnetoresistive element comprising magnetoresistive layer [12] and a soft magnetic layer [10] which are laminated with a nonmagnetic layer[11] provided there between, and antiferromagnetic layers formed on or below the magnetoresistive layer with a space there between corresponding to a track width Tw, wherein the antiferromagnetic layers and the magnetoresistive layer comprise an exchange coupling film according to Claim 1 [Hasegawa English translation, section 0036, drawing 4].

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

4. Claims 3 and 8 are rejected under 35 U.S.C. 103(a) as being obvious over Hasegawa et al. (hereinafter Hasegawa '647) (JPO English machine translation of JP 11-191647, publication date 7/13/1999) as applied to claim 1 above and further in view of Gill (US 6,456,469 B1).

- Regarding claims 3 and 8, Hasegawa '647 discloses all the features, *supra*, but does not teach a seed layer formed below the ferromagnetic layer and having a crystal structure mainly composed of a face-centered cubic crystal in which equivalent crystal planes represented by the {111} plane are preferentially oriented in parallel with the interface.

Gill teaches a seed layer [408] formed below a pinned layer [416] and in contact with an antiferromagnetic layer [410], and having a crystal structure mainly composed of a face-centered cubic crystal in which equivalent crystal planes represented by the {111} plane are preferentially oriented in parallel with the interface [col. 6, line 65 to col. 7, line 11; col. 10, lines 64-67].

It would have been obvious to one of ordinary skill in the art at the time the invention was made to provide the magnetoresistive element of Hasegawa with a seed layer formed below the ferromagnetic layer and having a crystal structure of a face-centered cubic crystal as taught by Gill.

The rationale is as follows: One of ordinary skill in the art at the time of the invention would have been motivated to provide the magnetoresistive element of Hasegawa with a seed layer formed below the ferromagnetic layer and having a crystal structure of a face-centered cubic crystal as taught by Gill in order to establish a consistent crystalline structure for adjacent layers [Gill; col. 6, lines 25-40].

5. Claims 4-7 are rejected under 35 U.S.C. 103(a) as being obvious over Hasegawa et al. (hereinafter Hasegawa '647) (JPO English machine translation of JP 11-191647, publication date 7/13/1999) and Gill (US 6,456,469 B1) as applied to claim 3 above and further in view of Lee et al. (hereinafter Lee) (US 5,731,936).

- Regarding claim 4, Hasegawa '647 and Gill disclose all the features, *supra*, but do not teach the seed layer is made of a NiFe alloy, Ni, a Ni-Fe-Y alloy (wherein Y is at least on element selected from Cr, Rh, Ta, Hf, Nb, Zr, and Ti) or a Ni-Y alloy.

Lee teaches a seed layer [74] composed of a Ni-Fe-Y alloy (wherein Y is at least on element selected from Cr, Rh, Ta, Hf, Nb, Zr, and Ti) [col. 2, lines 45-63].

Regarding claim 5, Lee teaches the seed layer is represented by the composition formula $(Ni_{1-x}Fe_x)_{1-y} Y_y$ (x and y are atomic ratios) wherein the atomic ratio x is 0 to 0.3, and the atomic ratio y is 0 to 0.5 [col. 6, lines 15-24].

Regarding claim 6, Lee discloses the seed layer is nonmagnetic at normal temperature [col. 6, lines 47-55].

It would have been obvious to one of ordinary skill in the art at the time the invention was made to provide the magnetoresistive element of Hasegawa and Gill with a seed layer composition as taught by Lee.

The rationale is as follows: One of ordinary skill in the art at the time of the invention would have been motivated to provide the magnetoresistive element of Hasegawa and Gill with a seed layer composition as taught by Lee in order to increase the MR coefficient [Lee; col. 2, lines 45-48].

- Regarding claim 7, Hasegawa '647 and Gill disclose all the features, *supra*, but do not teach an underlayer formed below the seed layer and comprising at least one element selected from Ta, Hf, Nb, Zr, Ti, Mo and W.

Lee discloses an underlayer formed below the seed layer and comprising at least one element selected from Ta, Hf, Nb, Zr, Ti, Mo and W [col. 2, lines 51-54].

It would have been obvious to one of ordinary skill in the art at the time the invention was made to provide the magnetoresistive element of Hasegawa and Gill with an underlayer formed below the seed layer as taught by Lee.

The rationale is as follows: One of ordinary skill in the art at the time of the invention would have been motivated to provide the magnetoresistive element of Hasegawa and Gill with an underlayer formed below the seed layer as taught by Lee in order to increase the MR coefficient of the magnetoresistive element [Lee; col. 2, lines 51-54].

Conclusion

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Christopher R. Magee whose telephone number is (703) 605-4256. The examiner can normally be reached on M-F, 8: 00 am-5: 30 pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, William Korzuch can be reached on (703) 305-6137. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

February 18, 2005

CR Magee
Christopher R. Magee
Patent Examiner
Art Unit 2653

CRM

William Korzuch
WILLIAM KORZUCH
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2600

PATENT ABSTRACTS OF JAPAN

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(30)Priority
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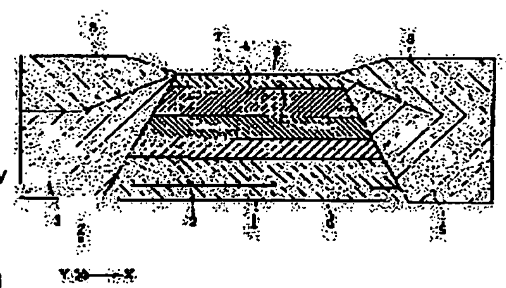
(54) EXCHANGE COUPLING FILM, MAGNETORESISTANCE EFFECT ELEMENT USING THIS EXCHANGE COUPLING FILM AND THIN-FILM MAGNETIC HEAD USING THE MAGNETORESISTANCE EFFECT ELEMENT

(57)Abstract:
PROBLEM TO BE SOLVED: To provide an exchange coupling film, formed such that when an antiferromagnetic material containing an element (X) ((X) is a platinum group element.) and an element Mn is used as an antiferromagnetic layer, a large exchange anisotropic magnetic field can be generated, and a magnetoresistance effect element using the exchange coupling film.
SOLUTION: An exchange coupling film is formed such that an antiferromagnetic layer 4 is formed of an X-Mn ((X) is a platinum group element.) layer and the compositional ratio of the (X) is regulated properly, whereby the interfacial structure between the layer 4 and a fixed magnetic layer 3 is put in a non-aligned form, and in the state, the layer 4 is subjected to heat treatment, whereby the crystal structure of the layer 4 is transformed so that a large exchange anisotropic magnetic field can be obtained. Thereby, it is possible to further improve the regenerating characteristics of the exchange coupling film in comparison with those of the conventional methods.



LEGAL STATUS

[Date of request for examination]	30.04.1999
[Date of sending the examiner's decision of rejection]	
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]	
[Date of final disposal for application]	
[Patent number]	2962415
[Date of registration]	06.08.1999
[Number of appeal against examiner's decision of	

rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

CLAIMS

[Claim(s)]

[Claim 1] By an antiferromagnetism layer and a ferromagnetic layer touching, forming them and performing heat treatment In the switched connection film with which an exchange anisotropy field occurs in the interface of said antiferromagnetism layer and ferromagnetic layer, and the magnetization direction of said ferromagnetic layer is fixed in the fixed direction said antiferromagnetism layer Switched connection film characterized by being formed with the antiferromagnetism ingredient which contains Elements X (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), and Mn at least, and the interface structure of said antiferromagnetism layer and ferromagnetic layer being in a disconformity condition.

[Claim 2] Switched connection film according to claim 1 with which a part of [at least] crystal structures of said antiferromagnetism layer after heat treatment serve as a face-centered square superlattice of L10 mold.

[Claim 3] Switched connection film according to claim 1 or 2 with which the crystal orientation of said antiferromagnetism layer and a ferromagnetic layer differs in the interface of said antiferromagnetism layer and ferromagnetic layer.

[Claim 4] The amount of preferred orientation of the {111} sides of said antiferromagnetism layer is switched connection film according to claim 3 which is smaller than the amount of preferred orientation of said ferromagnetic layer, or serves as non-orientation to the {111} sides of said ferromagnetic layer carrying out priority orientation in the direction parallel to an interface with said antiferromagnetism layer.

[Claim 5] The amount of preferred orientation of the {111} sides of said ferromagnetic layer is switched connection film according to claim 3 which is smaller than the amount of preferred orientation of said antiferromagnetism layer, or serves as non-orientation to the {111} sides of said antiferromagnetism layer carrying out priority orientation in the direction parallel to an interface with said ferromagnetic layer.

[Claim 6] Both the amount of preferred orientation of the {111} sides of said antiferromagnetism layer to a direction parallel to the interface of said antiferromagnetism layer and ferromagnetic layer and the amount of preferred orientation of the {111} sides of said ferromagnetic layer are switched connection film according to claim 3 with which it is small, or has become non-orientation, priority orientation of the crystal faces other than the aforementioned {111} sides is carried out in the direction parallel to an interface, and the crystal orientation of an antiferromagnetism layer and a ferromagnetic layer differs.

[Claim 7] It is the switched connection film according to claim 1 to 6 whose element X said antiferromagnetism layer is formed with a X-Mn alloy, and is Pt.

[Claim 8] the ratio of the lattice constants a and c of said antiferromagnetism [said antiferromagnetism layer is formed with a PtMn alloy, and] layer after heat treatment — the switched connection film according to claim 7 whose c/a is within the limits of 0.93-0.99.

[Claim 9] Said antiferromagnetism layer is a X-Mn-X' alloy (however, X). It is formed. the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — said X-Mn-X' alloy Switched connection film according to claim 1 to 6 a part of whose lattice point of the crystal lattice which consists of elements X and Mn it is the interstitial solid solution by which element X' trespassed upon the clearance between the space lattices which consist of elements X and Mn, or is the substitution solid solution permuted by element X'.

[Claim 10] The element X of the X-Mn-X' alloy used as said antiferromagnetism layer is switched connection film according to claim 9 which is Pt.

[Claim 11] Said element X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, And switched connection film according to claim 9 or 10 which is one sort or two sorts or more of elements among rare earth elements.

[Claim 12] Said element X' is switched connection film according to claim 11 which is one sort or two sorts or more of elements among Ne, Ar, Kr, and Xe.

[Claim 13] The presentation ratio of said element X' is switched connection film according to claim 9 to 12 which is at% and is within the limits of 0.2-10.

[Claim 14] The presentation ratio of said element X' is switched connection film according to claim 13 which is at% and is within the limits of 0.5-5.

[Claim 15] X:Mn is switched connection film of a presentation ratio with Elements X and Mn according to claim 13 or 14 which is within the limits of 4:6-6:4 comparatively.

[Claim 16] The X-Mn-X' alloy used as said antiferromagnetism layer is switched connection film according to claim 9 to 15 formed of a spatter.

[Claim 17] It is the switched connection film given in either of claims 1, 7, and 8 which said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed on the ferromagnetic layer, and the presentation ratio of X of a X-Mn alloy is at%, and are within the limits of 47-57.

[Claim 18] Said antiferromagnetism layer is a X-Mn-X' alloy (however, X). They are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os. X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — the switched connection film according to claim 13 to 15 which it is formed, said antiferromagnetism layer is formed on the ferromagnetic layer, and the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 47-57.

[Claim 19] The presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is switched connection film according to claim 17 or 18 which is at% and is within the limits of 50-56.

[Claim 20] It is the switched connection film given in either of claims 1, 7, and 8 which said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, and the presentation ratio of X of a X-Mn alloy is at%, and are within the limits of 44-57.

[Claim 21] Said antiferromagnetism layer is a X-Mn-X' alloy (however, X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — the switched connection film according to claim 13 to 15 which it is formed, said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, and the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 44-57.

[Claim 22] The presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is switched connection film according to claim 20 or 21 which is at% and is within the limits of 46-55.

[Claim 23] An antiferromagnetism layer and the fixed magnetic layer to which it is formed in in contact with this antiferromagnetism layer, and the magnetization direction is fixed by the exchange anisotropy field with said antiferromagnetism layer, The free magnetic layer formed in said fixed magnetic layer through the nonmagnetic conductive layer, The bias layer which arranges the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer, and the crossing direction, It has a fixed magnetic layer, a nonmagnetic conductive layer, and the conductive layer that gives a detection current to a free magnetic layer. The magneto-resistive effect component characterized by forming the fixed magnetic layer formed in contact with said antiferromagnetism layer and this antiferromagnetism layer with the switched connection film indicated by either claim 1 thru/or claim 22.

[Claim 24] The magneto-resistive effect component according to claim 23 currently formed with the switched connection film with which spacing of the width of recording track Tw was vacated for said free magnetic layer top or bottom, the laminating of the antiferromagnetism layer was carried out, and said antiferromagnetism layer and free magnetic layer were indicated by either claim 1 thru/or claim 22.

[Claim 25] The nonmagnetic conductive layer to which the laminating of the free magnetic layer was carried out up and down, and the fixed magnetic layer located on said one nonmagnetic conductive layer and under the nonmagnetic conductive layer of another side, It is located on said one fixed magnetic layer and under the fixed magnetic layer of another side. The antiferromagnetism layer which fixes the magnetization direction of each fixed magnetic layer in the fixed direction by the exchange anisotropy field, It has the bias layer which arranges the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer, and the crossing direction. The magneto-resistive effect component characterized by forming the fixed magnetic layer formed in contact with said antiferromagnetism layer and this antiferromagnetism layer with the switched connection film indicated by either claim 1 thru/or claim 22.

[Claim 26] The magneto-resistive effect component characterized by having the magnetic-reluctance layer and soft magnetism layer which were piled up through the non-magnetic layer, vacating spacing of the width of recording track Tw for said magnetic-reluctance layer top or bottom, forming an antiferromagnetism layer, and forming said antiferromagnetism layer and magnetic-reluctance layer with the switched connection film indicated by either claim 1 thru/or claim 22.

[Claim 27] The thin film magnetic head characterized by the thing of the magneto-resistive effect component indicated by claim 23 thru/or either of 26 for which the shielding layer is formed through the gap layer up and down.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] By the exchange anisotropy field which this invention consists of an antiferromagnetism layer and a ferromagnetic layer, and is generated in the interface of said antiferromagnetism layer and ferromagnetic layer The switched connection film with which the magnetization direction of said ferromagnetic layer is fixed in the fixed direction is started. When said especially antiferromagnetism layer is formed with the antiferromagnetism ingredient containing Elements X (Pt, Pd, etc.) and Mn, it is related with the switched connection film which enabled it to acquire a larger exchange anisotropy field, and the magneto-resistive effect component (a spin bulb mold thin film, AMR component) using this switched connection film.
[0002]
[Description of the Prior Art] A spin bulb mold thin film is one sort using giant magneto-resistance of a GMR (giant magnetoresistive) component, and detects the record field from record media, such as a hard disk. This spin bulb mold thin film has the point which was excellent in some — also in a GMR component, structure is comparatively simple and, moreover, resistance changes by the weak field.
[0003] Said spin bulb mold thin film is the simplest structure, and consists of an antiferromagnetism layer, a fixed magnetic layer, a nonmagnetic conductive layer, and a free magnetic layer. the exchange anisotropy field which said antiferromagnetism layer and fixed magnetic layer touch, and it is formed, and is generated in the interface of said antiferromagnetism layer and fixed magnetic layer — the magnetization direction of said fixed magnetic layer — the fixed direction — a single domain — it is-izing and fixed. Magnetization of a free magnetic layer is arranged in the magnetization direction of said fixed magnetic layer, and the crossing direction by the bias layer formed in the both sides.
[0004] Generally the Co-Pt (cobalt-platinum) alloy film etc. is used for Cu (copper) film and a bias layer by the Fe-Mn (iron-manganese) alloy film or the nickel-Mn (nickel-manganese) alloy film, the fixed magnetic layer, and the free magnetic layer at the nickel-Fe (nickel-iron) alloy film and the nonmagnetic conductive layer 3 at said antiferromagnetism layer.
[0005] In this spin bulb mold thin film, if the magnetization direction of said free magnetic layer is changed, electric resistance will change with the leakage fields from record media, such as a hard disk, by relation with the fixed magnetization direction of a fixed magnetic layer, and the leak field from a record medium is detected by the electrical-potential-difference change based on this electric resistance value change.
[0006] By the way, although the Fe-Mn alloy film and the nickel-Mn alloy film are used for an antiferromagnetism layer as mentioned above, the Fe-Mn alloy film has low corrosion resistance, and an exchange anisotropy field is small and blocking temperature is low with about 150 degrees C further. The problem that an exchange anisotropy field will disappear occurs by the rise of the chip temperature under the production process of a head, and head actuation because blocking temperature is low. On the other hand, compared with the Fe-Mn alloy film, the nickel-Mn alloy film has a comparatively large exchange anisotropy field, and, moreover, its blocking temperature is as high as about 300 degrees C. Therefore, it is more desirable to use the nickel-Mn alloy film for an antiferromagnetism layer rather than the Fe-Mn alloy film.
[0007] Moreover, B.Y.Wong, C.Mitsumata, S.Prakash, D.E.Laughlin, and T.Kobayashi:Journalof Applied The interface structure of said antiferromagnetism layer and fixed magnetic layer (NiFe alloy film) at the time of using the nickel-Mn alloy film as an antiferromagnetism layer is reported to Phsysics, vol.79, No10, and p.7896-p.7904 (1996).
[0008] This paper "the crystal adjustment condition in a NiFe/NiMn interface is maintained, and it is growing up so that the {111} sides of both NiFe and NiMn may become parallel to a film surface. The adjustment distortion by the interface is eased by introducing much twin crystal which makes a field parallel to a film surface a twin plane. However, regulation-ization of NiMn near the interface is low controlled by extant interface distortion, and whenever [regulation-ized] is high by it in the location distant from the interface. It is indicated as ".
[0009] In addition, the thing in the condition that the atom of an antiferromagnetism layer and a fixed magnetic layer corresponds by 1 to 1 is said, and disconformity says conversely the thing in the condition that there is no atom of the antiferromagnetism layer and fixed magnetic layer in an interface in the physical relationship of a pair. [in / in adjustment / an interface]
[0010] Although an exchange anisotropy field occurs in the interface of a NiMn alloy and a fixed magnetic layer by performing heat treatment when an antiferromagnetism layer is formed with a NiMn alloy, a NiMn alloy depends this on metamorphosing into a superlattice from an irregular grid by performing heat treatment.

[0011] If heat treatment is performed although the crystal structure of a NiMn alloy is a face-centered cubic lattice (henceforth an irregular grid) with the irregular array sequence of nickel and Mn atom before heat treatment is performed, the crystal structure will metamorphose into a face centred tetragonal lattice from a face-centered cubic lattice, and, moreover, an atomic location will regulation-ize it (henceforth a superlattice). in addition, the ratio of the lattice constants a and c of the nickel-Mn alloy film when the crystal structure becomes a superlattice completely -- c/a is 0.942.
[0012] Thus, since lattice constant ratio c/a of the NiMn alloy film which became a superlattice completely is a value comparatively near 1, even if it is comparatively small, therefore the interface structure of the NiMn alloy film and a fixed magnetic layer is in an adjustment condition, by performing heat treatment, a NiMn alloy metamorphoses into a superlattice from an irregular grid, and an exchange anisotropy field generates the grid distortion by the interface produced when metamorphosing into a superlattice from an irregular grid. In addition, the grid distortion in an interface is eased to some extent with twin crystal as indicated by the paper mentioned above.
[0013]
[Problem(s) to be Solved by the Invention] As mentioned above, although as for the NiMn alloy the exchange anisotropy field has become , and blocking temperature has also become as high as about 300 degrees C and it had the property which was excellent compared with the conventional FeMn alloy, it was not able to say comparatively that it was enough like the FeMn alloy about corrosion resistance.
[0014] So, recently, it excels in corrosion resistance, moreover a larger exchange anisotropy field than a NiMn alloy is generated, and the X-Mn alloy (X=Pt, Pd, Ir, Rh, Ru, Os) using platinum group metals as an antiferromagnetism ingredient which has high blocking temperature is capturing the spotlight. If the X-Mn alloy containing platinum group metals is used as an antiferromagnetism layer, a playback output can be raised compared with the former, and an exchange anisotropy field will be extinguished and it will be hard coming to also generate the fault that reproducing characteristics fall, by the rise of the chip temperature at the time of head drive actuation.
[0015] By the way, when the X-Mn alloy containing these platinum group metals is used as an antiferromagnetism layer, in order to generate an exchange anisotropy field, it is necessary to perform a membrane formation postheat treatment like the case where a NiMn alloy is used as an antiferromagnetism layer. According to the reference which was mentioned above in the case of the NiMn alloy, it was indicated that the interface structure with a fixed magnetic layer (NiFe alloy) was in an adjustment condition, but it turned out that an exchange anisotropy field hardly occurs even if it will heat-treat also in a X-Mn alloy (X is platinum group metals), if interface structure with a fixed magnetic layer is similarly made into the adjustment condition.
[0016] This invention is for solving the above-mentioned conventional technical problem, and when the antiferromagnetism ingredient containing Elements X (X is platinum group metals) and Mn is used as an antiferromagnetism layer, it relates to the switched connection film which enabled it to generate a large exchange anisotropy field, and the magneto-resistive effect component using this switched connection film.
[0017]
[Means for Solving the Problem] This invention by an antiferromagnetism layer and a ferromagnetic layer touching, forming them and performing heat treatment In the switched connection film with which an exchange anisotropy field occurs in the interface of said antiferromagnetism layer and ferromagnetic layer, and the magnetization direction of said ferromagnetic layer is fixed in the fixed direction said antiferromagnetism layer It is formed with the antiferromagnetism ingredient which contains Elements X (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), and Mn at least, and interface structure of said antiferromagnetism layer and ferromagnetic layer is characterized by being in a disconformity condition.
[0018] Moreover, it is desirable that a part of [at least] crystal structures of said antiferromagnetism layer after heat treatment serve as a face-centered square superlattice of L10 mold. It is desirable that the crystal orientation of said antiferromagnetism layer and a ferromagnetic layer furthermore differs according to the interface of said antiferromagnetism layer and ferromagnetic layer by this invention.
[0019] In this invention, to the {111} sides of said ferromagnetic layer carrying out priority orientation in the direction parallel to an interface with said antiferromagnetism layer, the amount of preferred orientation of the {111} sides of said antiferromagnetism layer is smaller than the amount of preferred orientation of said ferromagnetic layer, or serves as non-orientation.
[0020] Or to the {111} sides of said antiferromagnetism layer carrying out priority orientation in the direction parallel to an interface with said ferromagnetic layer, the amount of preferred orientation of the {111} sides of said ferromagnetic layer is smaller than the amount of preferred orientation of said antiferromagnetism layer, or serves as non-orientation.
[0021] Or both the amount of preferred orientation of the {111} sides of said antiferromagnetism layer to a direction parallel to the interface of said antiferromagnetism layer and ferromagnetic layer and the amount of preferred orientation of the {111} sides of said ferromagnetic layer are small, or serve as non-orientation, priority orientation of the crystal faces other than the aforementioned {111} sides is carried out in the direction parallel to an interface, and the crystal orientation of an antiferromagnetism layer and a ferromagnetic layer differs.
[0022] Moreover, in this invention, said antiferromagnetism layer is formed with a X-Mn alloy, and, as for Element X, it is desirable that it is Pt. furthermore, the ratio of the lattice constants a and c of said antiferromagnetism layer after heat treatment when said antiferromagnetism layer is formed with a PtMn alloy -- as for c/a, it is desirable that it is within the limits of 0.93-0.99.
[0023] Or at this invention, said antiferromagnetism layer is a X-Mn-X' alloy (however, X). It is formed. the inside of

Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — said X-Mn-X' alloy It is the interstitial solid solution by which element X' trespassed upon the clearance between the space lattices which consist of elements X and Mn, or a part of lattice point of the crystal lattice which consists of elements X and Mn is the substitution solid solution permuted by element X'. Especially the element X of the X-Mn-X' alloy used as said antiferromagnetism layer is Pt, i.e., being formed with the Pt-Mn-X' alloy is [said antiferromagnetism layer] desirable.

[0024] In this invention, in addition, element X' of the X-Mn-X' alloy used as said antiferromagnetism layer Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, And it is desirable that they are one sort or two sorts or more of elements among rare earth elements, and said element X' is one sort or two sorts or more of elements among Ne, Ar, Kr, and Xe more preferably.

[0025] Moreover, in this invention, when said antiferromagnetism layer is formed with a X-Mn-X' alloy, it is desirable that the presentation ratio of X' is at% and it is within the limits of 0.2-10, and it is within the limits of 0.5-5 more preferably.

[0026] When said antiferromagnetism layer is furthermore formed with a X-Mn-X' alloy by this invention, as for X:Mn, it is comparatively desirable that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4. In addition, as for the X-Mn-X' alloy used as said antiferromagnetism layer, being formed of a spatter is desirable.

[0027] In this invention, said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed on the ferromagnetic layer, it is at% and, as for the presentation ratio of X of a X-Mn alloy, it is desirable that it is within the limits of 47-57.

[0028] Moreover, at this invention, said antiferromagnetism layer is a X-Mn-X' alloy (however, X). They are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os. X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed and said antiferromagnetism layer is formed on the ferromagnetic layer, it is at% and, as for the presentation ratio of X+X' of a X-Mn-X' alloy, it is desirable that it is within the limits of 47-57.

[0029] It is more more desirable still that the presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and it is within the limits of 50-56 in this invention.

[0030] In this invention, said antiferromagnetism layer is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, it is at% and, as for the presentation ratio of X of a X-Mn alloy, it is desirable that it is within the limits of 44-57.

[0031] Moreover, at this invention, said antiferromagnetism layer is a X-Mn-X' alloy (however, X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed and said antiferromagnetism layer is formed in the bottom of a ferromagnetic layer, it is at% and, as for the presentation ratio of X+X' of a X-Mn-X' alloy, it is desirable that it is within the limits of 44-57.

[0032] It is more more desirable still that the presentation ratio of X of a X-Mn alloy or the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and it is within the limits of 46-55 in this invention.

[0033] The switched connection film formed as mentioned above is usable for various magneto-resistive effect components in this invention. First the single spin bulb mold thin film in this invention An antiferromagnetism layer and the fixed magnetic layer to which it is formed in in contact with this antiferromagnetism layer, and the magnetization direction is fixed by the exchange anisotropy field with said antiferromagnetism layer, The free magnetic layer formed in said fixed magnetic layer through the nonmagnetic conductive layer, The bias layer which arranges the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer, and the crossing direction, It has a fixed magnetic layer, a nonmagnetic conductive layer, and the conductive layer that gives a detection current to a free magnetic layer, and the fixed magnetic layer formed in contact with said antiferromagnetism layer and this antiferromagnetism layer is characterized by being formed with the switched connection film mentioned above.

[0034] Moreover, in this invention, spacing of the width of recording track Tw may be vacated for the above-mentioned single spin bulb mold thin-film the top or the bottom of a free magnetic layer, an antiferromagnetism layer may be formed, and said antiferromagnetism layer and free magnetic layer may be formed with the switched connection film mentioned above.

[0035] Moreover, the dual spin bulb mold thin film in this invention The nonmagnetic conductive layer to which the laminating of the free magnetic layer was carried out up and down, and the fixed magnetic layer located on said one nonmagnetic conductive layer and under the nonmagnetic conductive layer of another side, It is located on said one fixed magnetic layer and under the fixed magnetic layer of another side. The antiferromagnetism layer which fixes the magnetization direction of each fixed magnetic layer in the fixed direction by the exchange anisotropy field, It has the bias layer which arranges the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer, and the crossing direction, and the fixed magnetic layer formed in contact with said antiferromagnetism layer and this antiferromagnetism layer is characterized by being formed with the switched connection film mentioned above.

[0036] Furthermore, the AMR component in this invention is characterized by having the magnetic-reluctance layer and soft magnetism layer which were piled up through the non-magnetic layer, vacating spacing of the width of recording track Tw for said magnetic-reluctance layer top or bottom, forming an antiferromagnetism layer, and forming said antiferromagnetism layer and magnetic-reluctance layer with the switched connection film mentioned above. Moreover, the thin film magnetic head in this invention is characterized by the thing of the magneto-resistive effect component mentioned above for which the shielding layer is formed through the gap layer up and down.
[0037] When the antiferromagnetism ingredient which contains Elements X (any one sort or two sorts or more of elements among [X=] Pt, Pd, Ir, Rh, Ru, and Os) and Mn at least is used as an antiferromagnetism layer, it enables it to acquire an exchange anisotropy field to fitness by making interface structure with a ferromagnetic layer into a disconformity condition in this invention.
[0038] The reason for making interface structure with a ferromagnetic layer into a disconformity condition is for making the crystal structure of an antiferromagnetism layer metamorphose into a superlattice from an irregular grid at fitness, and generating a larger exchange anisotropy field, when heat-treating. Below, the relation of said disconformity condition and exchange anisotropy field is explained in full detail.
[0039] First, although a disconformity condition means that the atom by the side of said antiferromagnetism layer and the atom by the side of a ferromagnetic layer do not correspond to 1 to 1, but atomic physical relationship differs in the interface of an antiferromagnetism layer and a ferromagnetic layer, in order to make interface structure into a disconformity condition in this way, it is necessary to control the lattice constant of the antiferromagnetism layer before heat treatment to fitness.
[0040] In this invention, said antiferromagnetism layer is formed for example, with a X-Mn alloy (any one sort or two sorts or more of elements among [However, X] Pt, Pd, Ir, Rh, Ru, and Os).
[0041] He chooses the presentation ratio of X of said X-Mn alloy as fitness, and is trying for the difference of the value of the lattice constant of the X-Mn alloy before heat treatment and the value of the lattice constant of a ferromagnetic layer (for example, NiFe alloy) to become large in this invention.
[0042] Although the array sequence of X and Mn atom both serves as an irregular face-centered cubic lattice (henceforth an irregular grid), the crystal structure of a X-Mn alloy and the crystal structure of a ferromagnetic layer in a membrane formation phase (before heat treatment) Since the difference of the lattice constant of a X-Mn alloy and the lattice constant of a ferromagnetic layer is enlarged as mentioned above in this invention, the interface structure of the X-Mn alloy in a membrane formation phase (before heat treatment) and a ferromagnetic layer will be easy to be in a disconformity condition.
[0043] Thus, although the interface condition of an antiferromagnetism layer and a ferromagnetic layer is changed into the disconformity condition by choosing the presentation ratio of Element X proper in this invention when a X-Mn alloy (X is Pt, Pd, etc.) is used as an antiferromagnetism layer Furthermore by this invention, it is possible to be able to enlarge the lattice constant of an antiferromagnetism layer and to change the interface structure of said antiferromagnetism layer and ferromagnetic layer into a disconformity condition by making a X-Mn alloy contain element X', such as rare-gas elements (Ne, Ar, etc.).
[0044] Moreover, it is desirable to make it the crystal orientation of a X-Mn alloy or an X-Mn-X' alloy, and a ferromagnetic layer differ in this invention. The crystal amount of preferred orientation can be changed by terms and conditions, such as existence or nonexistence of a substrate layer, and a presentation ratio, power gas pressure at the time of spatter membrane formation, or the membranous order of a laminating.
[0045] Thus, it is because interface structure will stop being able to grow into a disconformity condition easily if for example, the {111} sides of a ferromagnetic layer carry out priority orientation of making it the crystal orientation of a X-Mn alloy or a X-Mn-X' alloy, and a ferromagnetic layer differ in parallel with a film surface and the {111} sides of a X-Mn alloy or a X-Mn-X' alloy are carrying out priority orientation in parallel with a film surface similarly.
[0046] So, in this invention, when the {111} sides of a ferromagnetic layer are carrying out priority orientation in the direction parallel to an interface with a X-Mn alloy or a X-Mn-X' alloy, for example, the amount of preferred orientation of the {111} sides of an X-Mn alloy or a X-Mn-X' alloy is smaller than the amount of preferred orientation of said ferromagnetic layer, or it is controlling to fitness so that it may become non-orientation, and becomes possible [maintaining interface structure at a disconformity condition].
[0047] As mentioned above, although an exchange anisotropy field occurs in the interface of a X-Mn alloy or a X-Mn-X' alloy, and a ferromagnetic layer by performing heat treatment after carrying out the laminating of a X-Mn alloy or a X-Mn-X' alloy, and the ferromagnetic layer so that interface structure may be in a disconformity condition The crystal structure of a X-Mn alloy or an X-Mn-X' alloy depends generating of this exchange anisotropy field on metamorphosing into the face centred tetragonal lattice decided by the array sequence of X and Mn atom having regularity from said irregular phase.
[0048] In addition, in this invention, said face centred tetragonal lattice is the so-called L10 type of face centred tetragonal lattice (henceforth a superlattice) which X atom occupies the core of the 4th page of a side face among the 6th page of a unit lattice, and Mn atom occupies at the core of the corner of a unit lattice, a top face, and an inferior surface of tongue, and a part of [at least] crystal structures of the X-Mn alloy after heat treatment or a X-Mn-X' alloy need to serve as said superlattice.
[0049] As mentioned above, although the crystal structure of a X-Mn alloy or an X-Mn-X' alloy metamorphoses into a superlattice from an irregular grid and a switched connection field occurs by heat-treating, as for grid distortion produced in the case of this transformation, the direction of a X-Mn alloy or a X-Mn-X' alloy is large compared with the NiMn alloy.

[0050] In this invention, as mentioned above, the interface structure of the X-Mn alloy before heat treatment or an X-Mn-X' alloy, and a ferromagnetic layer changes into a disconformity condition fitness-izing the presentation ratio of a X-Mn alloy, or by adding element X' as the 3rd element into a X-Mn alloy.
[0051] If the interface structure of an antiferromagnetism layer and a ferromagnetic layer is changed into a disconformity condition, by heat-treating, the crystal structure of an X-Mn alloy or a X-Mn-X' alloy will become easy to metamorphose into a superlattice from an irregular grid, therefore a big exchange anisotropy field will generate it in said interface. In addition, X-Mn alloys (X=Pt, Pd, etc.) or X-Mn-X' alloys (X'= Ne, Ar, etc.) have the property which was excellent in corrosion resistance compared with the FeMn alloy, the NiMn alloy, etc., and was excellent compared with the FeMn alloy etc. as an antiferromagnetism ingredient — blocking temperature is also high and an exchange anisotropy field (Hex) is still larger. Moreover, it is desirable to choose Pt as the element X which constitutes a X-Mn alloy or a X-Mn-X' alloy from this invention.
[0052] The switched connection film which consists of the antiferromagnetism layer formed with the X-Mn alloy explained in full detail above or the X-Mn-X' alloy and a ferromagnetic layer can be applied to a magneto-resistive effect component.
[0053] In this invention, the antiferromagnetism layer and fixed magnetic layer of a single spin bulb mold thin film and a dual spin bulb mold thin film are formed with said switched connection film, for example as said magneto-resistive effect component. It is possible to acquire the reproducing characteristics which became possible [fixing magnetization of said fixed magnetic layer in the fixed direction firmly] by this, and were excellent compared with the former.
[0054] Moreover, when arranging the magnetization direction of the free magnetic layer of for example, a single spin bulb mold thin film, or the magneto-resistive effect component layer of the AMR component in the fixed direction with an exchange bias method, an exchange bias layer, a free magnetic layer or an exchange bias layer, and a magnetic-reluctance layer may be formed with said switched connection film. It is possible for this to become possible to arrange magnetization of said free magnetic layer and a magnetic-reluctance layer with fitness in the fixed direction, and to acquire outstanding reproducing characteristics.
[0055]
[Embodiment of the Invention] Drawing 1 is the sectional view which looked at the structure of the single spin bulb mold thin film of the 1st operation gestalt of this invention from the ABS side side. In addition, drawing 1 fractures and shows only the central part of the component prolonged in the direction of X. This single spin bulb mold thin film is prepared in the trailing side edge section of the surfacing type slider formed in the hard disk drive unit etc., and detects record fields, such as a hard disk. In addition, the migration direction of magnetic-recording media, such as a hard disk, is a Z direction, and the direction of the leak field from a magnetic-recording medium is the direction of Y.

[0056] The substrate layer 6 formed by non-magnetic materials, such as Ta (tantalum), is formed in the bottom of drawing 1 . The laminating of the free magnetic layer 1, the nonmagnetic conductive layer 2, the fixed magnetic layer 3, and the antiferromagnetism layer 4 is carried out on this substrate layer 6. And the protective layers 7, such as Ta (tantalum), are formed on said antiferromagnetism layer 4.
[0057] Moreover, as shown in drawing 1 , the hard bias layers 5 and 5 are formed in the both sides of six layers from the substrate layer 6 to a protective layer 7, and the laminating of the conductive layers 8 and 8 is carried out on said hard bias layers 5 and 5.
[0058] In this invention, said free magnetic layer 1 and the fixed magnetic layer 3 are formed with a NiFe alloy, a CoFe alloy, Co alloy, Co, a CoNiFe alloy, etc. in addition, although the free magnetic layer 1 comes out further and it is formed as shown in drawing 1 , this may be formed by multilayer structure. That is, the structure where said free magnetic layer 1 may have the structure where the laminating of for example, a NiFe alloy and the CoFe alloy was carried out, and the laminating of a NiFe alloy and the Co was carried out is sufficient.
[0059] The nonmagnetic conductive layer 2 which intervenes between said free magnetic layers 1 and fixed magnetic layers 3 is formed by Cu. Furthermore, the hard bias layers 5 and 5 are formed with for example, the Co-Pt (cobalt-platinum) alloy, the Co-Cr-Pt (cobalt chrome-platinum) alloy, etc., and conductive layers 8 and 8 are formed by Cu (copper), W (tungsten), Cr (chromium), etc.
[0060] In this invention, the antiferromagnetism layer 4 currently formed on the fixed magnetic layer 3 is formed at least with the antiferromagnetism ingredient containing Elements X (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), and Mn.
[0061] In this invention, the interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 which are shown in drawing 1 is in the disconformity condition, and a part of [at least] crystal structures of said antiferromagnetism layer 4 in an interface serve as a face centred tetragonal lattice (henceforth a superlattice) of L10 mold.
[0062] Here, the face centred tetragonal lattice of L10 mold means what X atom (X=Pt, Pd, Ir, Rh, Ru, Os) occupies the core of the 4th page of a side face among the 6th page of a unit lattice, and Mn atom occupies at the core of the corner of a unit lattice, a top face, and an inferior surface of tongue.
[0063] Moreover, the interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 is desirable at the point that it will tend to be in a disconformity condition in this invention that the crystal orientation of the fixed magnetic layer 3 and the antiferromagnetism layer 4 differs.
[0064] drawing 1 — being shown — a single — a bulb — a mold — a thin film — **** — Ta — a substrate — a layer — six — covering — **** — since — said — a substrate — a layer — six — a top — forming — having —

free — a magnetic layer — one — nonmagnetic — a conductive layer — two — and — immobilization — a magnetic layer — three —{— 111 —}— a field — a film surface — receiving — being parallel — a direction — priority — orientation — carrying out — ****.

[0065] On the other hand, the {111} sides of the antiferromagnetism layer 4 formed on said fixed magnetic layer 3 are small compared with the amount of preferred orientation of the {111} sides of said fixed magnetic layer 3, or serve as non-orientation. That is, the crystal orientation near the interface of the fixed magnetic layer 3 and the antiferromagnetism layer 4 which are shown in drawing 1 is a different thing, therefore the structure in said interface will be easy to be in a disconformity condition.

[0066] Although interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 is made into the disconformity condition from the phase before heat treatment in this invention, this is because it is made to metamorphose into the superlattice which mentioned above the crystal structure of said antiferromagnetism layer 4 from the irregular grid (face-centered cubic lattice) and a fitness exchange anisotropy field can be acquired by heat-treating. If it says and changes and interface structure is in an adjustment condition, even if it heat-treats, the crystal structure of said antiferromagnetism layer 4 cannot metamorphose into a superlattice easily from an irregular grid, therefore the problem that an exchange anisotropy field is not acquired will arise.

[0067] In this invention, said antiferromagnetism layer 4 is formed with the X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os). It is desirable that said antiferromagnetism layer 4 is especially formed with the PtMn alloy by this invention. The X-Mn alloy, especially the PtMn alloy have the property which is excellent in thermal resistance compared with a FeMn alloy, a NiMn alloy, etc. which are used as an antiferromagnetism layer from the former, and was excellent as an antiferromagnetism ingredient — blocking temperature is also high and an exchange anisotropy field (Hex) is still larger.

[0068] the ratio of the lattice constants a and c of said antiferromagnetism layer 4 from which a part of [at least] crystal structures became a superlattice when said antiferromagnetism layer 4 is formed with the PtMn alloy after heat-treating in this invention that is, — as for c/a, it is desirable that it is within the limits of 0.93-0.99. the ratio of lattice constants a and c — if c/a becomes 0.93 or less — the crystal structure of said antiferromagnetism layer 4 — although all serve as a superlattice mostly, if it will be in such a condition, the adhesion of said fixed magnetic layer 3 and antiferromagnetism layer 4 falls, and film peeling etc. generates and is not desirable. the ratio of lattice constants a and c — it becomes [the exchange anisotropy field of the crystal structure of said antiferromagnetism layer 4 generated in the interface of said antiferromagnetism layer 4 and fixed magnetic layer 3 by all becoming an irregular grid mostly] small and is not desirable if c/a becomes 0.99 or more.

[0069] By the way, in the phase before heat treatment, when said antiferromagnetism layer 4 is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os), in order to make interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 into a disconformity condition, by this invention, the presentation ratio of said X-Mn alloy is set up in the following numeric value.

[0070] As moreover shown in drawing 1, when said antiferromagnetism layer 4 is formed with a X-Mn alloy (however, X is any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os) and said antiferromagnetism layer 4 is formed on the fixed magnetic layer 3, the presentation ratio of the element X of a X-Mn alloy is at%, and it is desirable that it is within the limits of 47-57. More preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 50-56.

[0071] If the antiferromagnetism layer 4 is formed in presentation Hinai mentioned above, the difference of the lattice constant of said antiferromagnetism layer 4 of a before [heat treatment (i.e., the phase where the crystal structure serves as an irregular grid)], and the lattice constant of the fixed magnetic layer 3 can be enlarged, therefore the interface structure of said fixed magnetic layer 3 and antiferromagnetism layer 4 can be maintained at a disconformity condition before heat treatment.

[0072] If it heat-treats in this condition, as the exchange anisotropy field occurred and mentioned above by change of the crystal structure of said antiferromagnetism layer 4, the presentation ratio of the presentation ratio of the element X of a X-Mn alloy is at%, and it is possible to acquire the exchange anisotropy field more than 400 (Oe: oersted) as it is within the limits of 47-57. Moreover, the presentation ratio of the element X of a X-Mn alloy is at%, and it is possible to acquire the exchange anisotropy field more than 600 (Oe) as it is within the limits of 50-56.

[0073] Thus, when a X-Mn alloy is used as an antiferromagnetism layer 4 in this invention, it is possible to maintain the interface structure of said antiferromagnetism layer 4 and fixed magnetic layer 3 before heat treatment at a disconformity condition by forming within limits which mentioned the presentation ratio of Element X above. Moreover, it is possible by adding element X' as the 3rd element into a X-Mn alloy in this invention to be able to enlarge the lattice constant of the antiferromagnetism layer 4 and to change the interface structure of the antiferromagnetism layer 4 and the fixed magnetic layer 3 before heat treatment into a disconformity condition.

[0074] The X-Mn-X' alloy which added element X' to the X-Mn alloy is the interstitial solid solution by which element X' trespassed upon the clearance between the space lattices which consist of elements X and Mn, or a part of lattice point of the crystal lattice which consists of elements X and Mn is the substitution solid solution permuted by element X'. The solid solution was crossed to the large presentation range, and has pointed out the thing of the solid-state with which the component was mixed with homogeneity here. In addition, as for Element X, in this invention, it is desirable that it is Pt.

[0075] By the way, in this invention, said X-Mn-X' alloy is formed by the spatter. Said X-Mn-X' alloy is formed by non-equilibrium by the spatter, and a part of lattice point of the crystal lattice which the formed X-Mn-X' alloy trespasses upon the clearance between space lattices where element X' in the film consists of elements X and Mn,

or consists of elements X and Mn is permuted by element X' by it. thus, said element X' is an invasion mold at the grid of a X-Mn alloy — it is — by dissolving with a permutation mold, a grid can be extended and the lattice constant of the antiferromagnetism layer 4 becomes large compared with the case where element X' is not added.
[0076] Moreover, although it is possible to use various elements as element X' in this invention, if a reactant high halogen, O (oxygen), etc. are used, these carry out a chemical bond only to Mn alternatively, are considered with it becoming impossible to maintain the crystal structure of a face-centered cubic, and are not desirable. Concrete element X' in this invention Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, And they are one sort or two sorts or more of elements among rare earth elements (Sc, Y, and lanthanoids (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu)).
[0077] If the presentation ratio of said element X' becomes large too much when using element X' which dissolves especially with a permutation mold although the lattice constant of the antiferromagnetism layer 4 can be enlarged by the spatter even if it uses any of various element X' which showed above, the property as antiferromagnetism will fall and the switched connection field generated in an interface with the fixed magnetic layer 3 will become small.
[0078] By this invention, it especially dissolves with an invasion mold, and it is supposed that it is desirable to use the rare-gas element (one sort or two sorts or more among Ne, Ar, Kr, and Xe) of inert gas as element X'. It is gas by which it is not greatly affected in an antiferromagnetism property even if a rare-gas element contains in the film, since a rare-gas element is inert gas, and Ar etc. is further introduced in the sputtering system from the former as sputtering gas, and is only adjusting gas pressure and spatter particle energy proper, and Ar can be made to invade into the film easily.
[0079] In addition, although it is difficult to contain a lot of element X' in the film when the element of a gas system is used for element X', in the case of rare gas, minute amount invasion is only carried out into the film, and it is checked by experiment that the switched connection field generated by heat treatment can be enlarged by leaps and bounds.
[0080] In addition, in this invention, the range of the presentation ratio of element X' is set up, and the desirable presentation range of said element X' is 0.2 to 10 at at%, is at% more preferably, and is 0.5 to 5. Moreover, as for X:Mn, it is comparatively desirable at this time that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4. It is possible to enlarge the switched connection field generated in the interface of the antiferromagnetism layer 4 and the fixed magnetic layer 3 by being able to enlarge the lattice constant of the antiferromagnetism layer 4 in a membrane formation phase (before heat treatment) if it is within the limits and X:Mn is adjusted [above-mentioned] comparatively of the presentation ratio of element X' and a presentation ratio with Elements X and Mn, and moreover heat-treating compared with the case where element X' is not contained.
[0081] Furthermore at this invention, it is a X-Mn-X' alloy (however, X). They are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os. X' Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, As shown in drawing 1 , when the formed antiferromagnetism layer 4 is formed on the fixed magnetic layer 3, the presentation ratio of X+X' of said X-Mn-X' alloy is at% and the inside of rare earth elements — one sort or two sorts or more of elements — it is — It is desirable that it is within the limits of 47-57, and more preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 50-56.
[0082] the direction of Y which shows magnetization of said fixed magnetic layer 3 to drawing 1 by the switched connection field generated in the interface of the antiferromagnetism layer 4 and the fixed magnetic layer 3 by heat-treating — a single domain — it is-izing and fixed. in addition, when element X' of the X-Mn-X' alloy used as an antiferromagnetism layer 4 is the element of for example, a gas system Although the presentation ratio of element X' after heat treatment becomes small, or said X' may slip out out of the film completely and a presentation may become X-Mn from the presentation ratio of element X' in the phase which said element X' fell out out of the film, came out, and was formed by heat-treating If the interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 in a membrane formation phase (before heat treatment) is in the disconformity condition, by heat-treating the crystal structure of said antiferromagnetism layer 4 It is possible to metamorphose into a superlattice from an irregular grid (face-centered cubic lattice) at fitness, and to acquire a large exchange anisotropy field. Moreover, the free magnetic layer 1 is arranged in the direction of illustration X by the hard bias layers 5 and 5 currently formed in the both sides.
[0083] In the single spin bulb mold thin film shown in drawing 1 , if the stationary current (sense current) is given to the free magnetic layer 1, the nonmagnetic conductive layer 2, and the fixed magnetic layer 3 from a conductive layer 8 and a field is moreover given in the direction of Y from a record medium, the magnetization direction of the free magnetic layer 1 will change from X towards the direction of Y. At this time, a lifting and electric resistance change [conduction electron] dispersion by the interface of the nonmagnetic conductive layer 2 and the fixed magnetic layer 3, or the interface of the nonmagnetic conductive layer 2 and the free magnetic layer 1. Therefore, an electrical potential difference can change and a detection output can be obtained.
[0084] Drawing 2 is the sectional view showing the structure of the single spin bulb mold thin film of the 2nd operation gestalt of this invention. As shown in drawing 2 , the laminating of the substrate layer 6, the antiferromagnetism layer 4, the fixed magnetic layer 3, the nonmagnetic conductive layer 2, and the free magnetic layer 1 is continuously carried out from the bottom. In addition, the antiferromagnetism layer 4 shown in drawing 2 is a X-Mn alloy (however, X) like the antiferromagnetism layer 4 shown in drawing 1 . they are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os — desirable — a PtMn alloy or a X-Mn-X' alloy (however, X') Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb,

Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed. In addition, the fixed magnetic layer 3, the nonmagnetic conductive layer 2, and the free magnetic layer 1 are formed with the quality of the material explained by drawing 1 .

[0085] Also in this example, the interface structure of the fixed magnetic layer 3 and the antiferromagnetism layer 4 is in the disconformity condition, and a part of [at least] crystal structures of said antiferromagnetism layer 4 in an interface serve as a face centred tetragonal lattice (henceforth a superlattice) of L10 mold.

[0086] Moreover, although priority orientation of the {111} sides of said antiferromagnetism layer 4 formed on the substrate layer 6 of Ta is carried out in the direction parallel to an interface If the fixed magnetic layer 3 is formed on said antiferromagnetism layer 4 as shown in drawing 2 , the amount of preferred orientation to the direction of an interface of the {111} sides of said fixed magnetic layer 3 will be smaller than the amount of preferred orientation of said antiferromagnetism layer 4, or will tend to become [tend] non-orientation. Thus, in drawing 2 , it is possible for the crystal orientation of said antiferromagnetism layer 4 and fixed magnetic layer 3 in an interface to differ, therefore to make interface structure into a disconformity condition more.

[0087] By the way, the antiferromagnetism layer 4 is a X-Mn alloy (however, X). the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is, as it is formed and is shown in drawing 2 When the antiferromagnetism layer 4 is formed in the bottom of the fixed magnetic layer 3, the presentation ratio of the element X of the X-Mn alloy which constitutes the antiferromagnetism layer 4 is at%, and it is desirable that it is within the limits of 44-57. If it is this within the limits, it is possible to acquire the exchange anisotropy field more than 400 (Oe). More preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 46-55. If it is this within the limits, it is possible to acquire the exchange anisotropy field more than 600 (Oe).

[0088] Thus, it is because that an exchange anisotropy field can be greatly carried out to it being presentation within the limits mentioned above can enlarge the difference of the lattice constant (irregular grid) of the antiferromagnetism layer 4 before heat treatment, and the lattice constant of the fixed magnetic layer 3 and interface structure before heat treatment can be made into a disconformity condition. Therefore, by heat-treating, it becomes possible to make a part of [at least] crystal structures of said antiferromagnetism layer 4 in an interface metamorphose into a superlattice required in order to demonstrate an exchange anisotropy field from an irregular grid.

[0089] Moreover, said antiferromagnetism layer 4 is a X-Mn-X' alloy (however, X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — said X-Mn-X' alloy, when formed A part of lattice point of the crystal lattice which is formed of a spatter, and serves as an interstitial solid solution by which element X' trespassed upon the clearance between the space lattices which consist of elements X and Mn, or consists of elements X and Mn serves as a substitution solid solution permuted by element X'.

[0090] The lattice constant of the antiferromagnetism layer 4 which contains element X' in the film becomes large compared with the lattice constant of the antiferromagnetism layer 4 which does not contain said element X', and can maintain the interface structure of the antiferromagnetism layer 4 and the fixed magnetic layer 3 in a membrane formation phase (before heat treatment) at a disconformity condition.

[0091] In addition, by this invention, the presentation ratio of element X' occupied in the film is made into within the limits of 0.2-10 at at%, and the more desirable presentation range is made into within the limits of 0.5-5 at at%. Moreover, it is said presentation within the limits, element X' is formed, and the thing of a presentation ratio with Elements X and Mn within the limits of 4:6-6:4, then a larger switched connection field are acquired [a thing] for X:Mn is still more possible comparatively.

[0092] Moreover, as shown in drawing 2 , when the antiferromagnetism layer 4 formed with the X-Mn-X' alloy is formed in the fixed magnetic layer 3 bottom in this invention, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and it is desirable that it is within the limits of 44-57. More preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 46-55.

[0093] in addition, the exchange anisotropy field which generates magnetization of the fixed magnetic layer 3 shown in drawing 2 in an interface with the antiferromagnetism layer 4 — the direction of illustration Y — a single domain -- it is-izing and fixed.

[0094] As shown in drawing 2 , on the free magnetic layer 1, spacing of the width of recording track Tw is vacated, and the exchange bias layer 9 (antiferromagnetism layer) is formed. In addition, this exchange bias layer 9 is a X-Mn alloy (however, X). they are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os — desirable — a PtMn alloy or a X-Mn-X' alloy (however, X') Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed.

[0095] The presentation ratio of the element X of a X-Mn alloy is at%, and has become within the limits of 47-57. More preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 50-56. In addition, this presentation range is the same as the presentation range of the antiferromagnetism layer 4 explained by drawing 1 . Moreover, in the case of a X-Mn-X' alloy, the presentation ratio of element X' is at% and it is within the limits of 0.2-10, and the more desirable presentation range is at% and is within the limits of 0.5-5. Moreover, as for X:Mn, it is comparatively desirable that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4. Furthermore, it is desirable to have become within the limits of 47-57, more preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and it is [the presentation ratio of X+X' of a X-Mn-X' alloy is at% and]

within the limits of 50-56.
[0096] Although the interface structure of the free magnetic layer 1 and the exchange bias layer 9 will be in a disconformity condition for it to be presentation within the limits mentioned above and the exchange anisotropy field more than 400 (Oe) can be acquired in an interface at least As shown in drawing 2 , said exchange bias layers 9 and 9 Since it is not formed in the width-of-recording-track Tw part, it is strongly influenced by the amount of [of the free magnetic layer 1] both ends of an exchange anisotropy field, and is single-domain-ized in the direction of illustration X, and magnetization of the width-of-recording-track Tw field of the free magnetic layer 1 is arranged with extent which reacts to an external magnetic field in the direction of illustration X at fitness.
[0097] Thus, in the formed single spin bulb mold thin film, magnetization of the width-of-recording-track Tw field of the free magnetic layer 1 changes with the external magnetic fields of the direction of illustration Y in the direction of illustration Y from illustration X. Electric resistance changes by the relation between fluctuation of the direction of magnetization within this free magnetic layer 1, and the fixed magnetization direction (the direction of illustration Y) of the fixed magnetic layer 3, and the leak field from a record medium is detected by the electrical-potential-difference change based on this electric resistance value change.
[0098] Drawing 3 is the sectional view showing the structure of the dual spin bulb mold thin film of the 3rd operation gestalt of this invention. As shown and shown in drawing, the laminating of the substrate layer 6, the antiferromagnetism layer 4, the fixed magnetic layer 3, the nonmagnetic conductive layer 2, and the free magnetic layer 1 is continuously carried out from the bottom. Furthermore on said free magnetic layer 1, the laminating of the nonmagnetic conductive layer 2, the fixed magnetic layer 3, the antiferromagnetism layer 4, and the protective layer 7 is carried out continuously. Moreover, the laminating of the hard bias layers 5 and 5 and the conductive layers 8 and 8 is carried out to the both sides of the multilayers from the substrate layer 6 to a protective layer 7. In addition, each class is formed with the same quality of the material as the quality of the material explained by drawing 1 and drawing 2 .
[0099] As shown in drawing 3 , the antiferromagnetism layer 4 currently formed below the free magnetic layer 1 The presentation ratio of the element X of the X-Mn alloy which constitutes said antiferromagnetism layer 4 is at% like [since it is formed in the bottom of the fixed magnetic layer 3] the antiferromagnetism layer 4 shown in drawing 2 . It is desirable that it is within the limits of 44-57, and more preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 46-55.
[0100] Moreover, the antiferromagnetism layer 4 currently formed above the free magnetic layer 1 The presentation ratio of the element X of the X-Mn alloy which constitutes said antiferromagnetism layer 4 is at% like [since it is formed on the fixed magnetic layer 3] the antiferromagnetism layer 4 shown in drawing 1 . It is desirable that it is within the limits of 47-57, and more preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 50-56.
[0101] If it is this presentation within the limits, since the difference of the lattice constant of the fixed magnetic layer 3 and the lattice constant of the antiferromagnetism layer 4 before heat treatment can be enlarged, it is possible by being able to change the interface structure before heat treatment into a disconformity condition, therefore heat-treating to make a part of crystal structures of said antiferromagnetism layer 4 in an interface metamorphose into a superlattice required to demonstrate an exchange anisotropy field from an irregular grid. in addition, the ratio of the lattice constants a and c of said antiferromagnetism layer 4 after heat treatment when said antiferromagnetism layer 4 is formed with a PtMn alloy — as for c/a, it is desirable that it is within the limits of 0.93-0.99. Moreover, since the crystal orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3 also differs, it is possible to change interface structure into a disconformity condition more.
[0102] if it comes out in the presentation range mentioned above, it is possible to acquire the exchange anisotropy field more than at least 400 (Oe), but it is more possible to make large the range of the presentation ratio of the element X of a X-Mn alloy a little rather than the direction which forms the antiferromagnetism layer 4 in the bottom of the fixed magnetic layer 3 forms on the fixed magnetic layer 3.
[0103] Moreover, when the antiferromagnetism layer 4 is formed with a X-Mn-X' alloy, the presentation ratio of element X' is at% and it is within the limits of 0.2-10, and the more desirable presentation range is at% and is within the limits of 0.5-5. Moreover, as for X:Mn, it is comparatively desirable that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4.
[0104] In the case of the antiferromagnetism layer 4 currently furthermore formed below the free magnetic layer 1, it is desirable that the presentation ratio of X+X' of the X-Mn-X' alloy which constitutes said antiferromagnetism layer 4 is at%, and it is within the limits of 44-57, and more preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 46-55.
[0105] Moreover, in the case of the antiferromagnetism layer 4 currently formed above the free magnetic layer 1, it is desirable that the presentation ratio of X+X' of the X-Mn-X' alloy which constitutes said antiferromagnetism layer 4 is at%, and it is within the limits of 47-57, and more preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 50-56.
[0106] If it is above-mentioned presentation within the limits, it is possible by being able to enlarge the difference of the lattice constant of the fixed magnetic layer 3 and the lattice constant of the antiferromagnetism layer 4 before heat treatment, and being able to change the interface structure before heat treatment into a disconformity condition, therefore heat-treating to make a part of crystal structures of said antiferromagnetism layer 4 in an interface metamorphose into a superlattice required to demonstrate an exchange anisotropy field from an irregular grid.

[0107] in addition, the single spin bulb mold thin film which also shows this dual spin bulb mold thin film to drawing 1 — the same — the fixed magnetic layer 3 — an exchange anisotropy field — the direction of illustration Y — a single domain — are-izing, and it is fixed and magnetization of the free magnetic layer 1 is arranged in the direction of illustration X in response to the effect of the hard bias layers 5 and 5.
[0108] If the stationary current is given to the free magnetic layer 1, the nonmagnetic conductive layer 2, and the fixed magnetic layer 3 from a conductive layer 8 and a field is moreover given in the direction of Y from a record medium When magnetization of the free magnetic layer 1 is changed in the direction of Y from illustration X and dispersion of the conduction electron for which it depended on spin by the interface of the nonmagnetic conductive layer 2 and the free magnetic layer 1 and the interface of the nonmagnetic conductive layer 2 and the fixed magnetic layer 3 at this time takes place Electric resistance changes and the leakage field from a record medium is detected.
[0109] in addition, in the single spin bulb mold thin film shown in drawing 1 and drawing 2 The location from which dispersion of the electron depending on spin is started The interface of the nonmagnetic conductive layer 2 and the free magnetic layer 1, and by the dual spin bulb mold thin film shown in drawing 3 , to being two places of the interface of the nonmagnetic conductive layer 2 and the fixed magnetic layer 3 Since the location where dispersion of conduction electron takes place is a total of four places of two interfaces of the nonmagnetic conductive layer 2 and the free magnetic layer 1, and two interfaces of the nonmagnetic conductive layer 2 and the fixed magnetic layer 3, The direction of a dual spin bulb mold thin film is able to obtain large resistance rate of change compared with a single spin bulb mold thin film.
[0110] Drawing 4 is the sectional view showing the structure of the AMR mold thin film of the 4th operation gestalt of this invention. As shown in drawing, the laminating of the soft magnetism layer (SAL layer) 10, a non-magnetic layer (SHUNT layer) 11, and the magnetic-reluctance layer (MR layer) 12 is continuously carried out from the bottom. For example, said soft magnetism layer 10 is formed with a Fe-nickel-Nb alloy, and the non-magnetic layer 11 is formed for Ta film and the magnetic-reluctance layer 12 with the NiFe alloy.
[0111] On said magnetic-reluctance layer 12, the exchange bias layers (antiferromagnetism layer) 9 and 9 are formed in the part of the direction both sides of X which opened the width of recording track Tw, and the conductive layers 13 and 13 formed by Cr film etc. are further formed on said exchange bias layers 9 and 9.
[0112] the exchange bias layers 9 and 9 which show the exchange bias layers 9 and 9 shown in drawing 4 to drawing 2 — the same — a X-Mn alloy — it is preferably formed with the PtMn alloy, and the presentation ratio of the element X of an X-Mn alloy is at%, and has become within the limits of 47-57. More preferably, the presentation ratio of the element X of a X-Mn alloy is at%, and is within the limits of 50-56.
[0113] Moreover, said exchange bias layers 9 and 9 a X-Mn-X' alloy (it Au(s) and Pb(s) however, X' — Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, and Re —) and the inside of rare earth elements — one sort or two sorts or more of elements — it is — it is formed, and the presentation ratio of element X' is at%, and it is within the limits of 0.2-10, and it is [the more desirable presentation range is at% and] within the limits of 0.5-5. Moreover, as for X:Mn, it is comparatively desirable that it is [of a presentation ratio with Elements X and Mn] within the limits of 4:6-6:4. Moreover, like the exchange bias layers 9 and 9 shown in drawing 2 , the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and the exchange bias layers 9 and 9 shown in drawing 4 have become within the limits of 47-57. More preferably, the presentation ratio of X+X' of a X-Mn-X' alloy is at%, and is within the limits of 50-56.
[0114] If it forms within limits which mentioned the presentation ratio of an X-Mn alloy or an X-Mn-X' alloy above By heat-treating by the interface structure of said exchange bias layers 9 and 9 and magnetic-reluctance layer 12 being in a disconformity condition When the thickness of the magnetic-reluctance layer 12 of a NiFe alloy is 200-300A The exchange anisotropy field of about 40-110 (Oe) is acquired in said interface, and it divides. The thickness of the magnetic-reluctance layer of a NiFe alloy in the case of about 200A The exchange anisotropy field of about 60-110 (Oe) is acquired, and area B of the magnetic-reluctance layer 12 shown in drawing 4 is single-domain-ized in the direction of illustration X. And it is induced by this and magnetization of the area A of said magnetic-reluctance layer 12 is arranged in the direction of illustration X. Moreover, the current field generated in case a detection current flows the magnetic-reluctance layer 12 is impressed to the soft magnetism layer 10 in the direction of Y, and a horizontal bias field is given to the area A of the magnetic-reluctance layer 12 in the direction of Y by the magnetostatic binding energy which the soft magnetism layer 10 brings about. By giving this horizontal bias layer to the area A of the magnetic-reluctance layer 12 single-domain-ized in the direction of X, the resistance change (magneto-resistive-effect property: the H-R effectiveness property) to field change of the area A of the magnetic-reluctance layer 12 is set as the condition of having linearity. The migration direction of a record medium is a Z direction, if a leakage field is given in the direction of illustration Y, the resistance of the area A of the magnetic-reluctance layer 12 will change, and this will be detected as electrical-potential-difference change.
[0115] As explained in full detail above, at this invention, it is a X-Mn alloy (however, X) about the antiferromagnetism layer 4 (or exchange bias layer 9). In case [which are any one sort or two sorts or more of elements among Pt, Pd, Ir, Rh, Ru, and Os] it forms with a PtMn alloy preferably, by adjusting the presentation ratio of said antiferromagnetism layer 4 to fitness It is possible to be able to make into a disconformity condition interface structure of said antiferromagnetism layer 4 and the fixed magnetic layer 3 (or the free magnetic layer 1 or the magnetic-reluctance layer 12) formed in contact with this antiferromagnetism layer 4, therefore to be able to acquire a bigger exchange anisotropy field, and to raise reproducing characteristics compared with the former. Or it is said antiferromagnetism layer 4 (or exchange bias layer 9) as the 3rd element in addition to Elements X and Mn

Element X' (however, X') Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is, since the lattice constant of the antiferromagnetism layer 4 can be enlarged compared with the case where said element X' is not added by adding Interface structure of said antiferromagnetism layer 4 and the fixed magnetic layer 3 (or the free magnetic layer 1 or the magnetic-reluctance layer 12) formed in contact with this antiferromagnetism layer 4 can be made into a disconformity condition. Therefore, a bigger exchange anisotropy field can be acquired and it is possible to raise reproducing characteristics compared with the former. Moreover, it is desirable to make the crystal orientation of the antiferromagnetism layer 4 and the fixed magnetic layer 3 differ at the point which interface structure can be made easier to change into a disconformity condition.

[0116] Moreover, although it is because the crystal structure of said antiferromagnetism layer 4 can be made to metamorphose into a superlattice from an irregular grid when it heat-treats that an exchange anisotropy field can be acquired by what interface structure is made into the disconformity condition for, since a problem will arise in adhesion etc. if all the crystal structures metamorphose into a superlattice, it is desirable that only a part of crystal structures are metamorphosing into the superlattice. for example, the ratio of the lattice constants a and c of said antiferromagnetism layer 4 after heat treatment when said antiferromagnetism layer 4 is formed with a PtMn alloy -- it is desirable that c/a is within the limits of 0.93-0.99 (the case where all the crystal structures incidentally carry out a variant to a superlattice — the ratio of said lattice constants a and c —.c/a is 0.918).

[0117] In addition, in this invention, it does not limit to the structure which shows the structure of a magneto-resistive effect component layer in drawing 1 - drawing 4 . For example, without forming the hard bias layers 5 and 5 in the case of the single spin bulb mold thin film shown in drawing 1 Without forming the exchange bias layers 9 and 9 in the case of the single spin bulb mold thin film which may vacate spacing of the width of recording track Tw for the free magnetic layer 1 bottom, may form an exchange bias layer, and is shown in drawing 2 the both sides of six layers from the substrate layer 6 to a protective layer 7 — or a hard bias layer may be formed in the both sides of the free magnetic layer 1 at least.

[0118] Drawing 5 is the sectional view in which the magneto-resistive effect component layer shown in drawing 4 from drawing 1 was formed and which read and looked at the structure of a head from the opposed face side with a record medium. A sign 20 is the lower shielding layer formed for example, with the NiFe alloy etc., and the lower gap layer 21 is formed on this lower shielding layer 20. Moreover, on the lower gap layer 21, the magneto-resistive effect component layer 22 shown in drawing 4 is formed from drawing 1 , further, the up gap layer 23 is formed on said magneto-resistive effect component layer 22, and the up shielding layer 24 formed with the NiFe alloy etc. is formed on said up gap layer 23.

[0119] Said lower gap layer 21 and the up gap layer 23 are formed of insulating materials, such as SiO2 and aluminum 2O3 (alumina). As shown in drawing 5 , the die length from the lower gap layer 21 to the up gap layer 23 is gap length Gl, and it can respond to high recording density-ization, so that this gap length Gl is small.

[0120]

[Example] In this invention, the multilayers which consist of the film configuration shown below first were formed, and it investigated about the relation between the amount of Pt(s) of one element which constitutes an antiferromagnetism layer, and the lattice constant of said antiferromagnetism layer. As a film configuration, they are Si substrate / alumina / substrate layer:Ta (100) / fixed magnetic layer:NiFe (300) / antiferromagnetism layer from the bottom :P The laminating was carried out in the order of tMn (300)/Ta (100). In addition, the numeric value in the above-mentioned parenthesis expresses thickness, and a unit is angstrom. An experiment is the phase which does not heat-treat and asked for the relation between the amount of Pt(s), and the lattice constant of an antiferromagnetism layer from the peak location of a diffraction pattern by the theta / the 2theta method of an X diffraction.

[0121] It turns out that the lattice constant of an antiferromagnetism layer (PtMn) is large as are shown in drawing 6 and the amount of Pt(s) increases. Moreover, as shown in drawing, the range of the NiFe alloy which constitutes a fixed magnetic layer, a CoFe alloy, or the lattice constant of Co is about 3.5 to 3.6.

[0122] Next, membranes were formed by the DC magnetron sputtering method, and two multilayers in which the antiferromagnetism layer was formed to the bottom of a fixed magnetic layer or a top were investigated about the relation of the amount of Pt(s) (one element which constitutes an antiferromagnetism layer) and an exchange anisotropy field after heat-treating. The experimental result is shown in drawing 7 .

[0123] An antiferromagnetism layer as a film configuration currently formed in the bottom of a fixed magnetic layer Si substrate / alumina / substrate layer [from the bottom]: — Ta(50) / antiferromagnetism layer :P A laminating is carried out in the order of Ta (100). tMn (300) / fixed magnetic layer: — Co90Fe10 (30) / protective layer: — Said antiferromagnetism layer carried out the laminating from the bottom as a film configuration currently formed on the fixed magnetic layer in the order of Si substrate / alumina / Ta(50) / fixed magnetic layer:Co90Fe10 (30) / antiferromagnetism layer (300) / protective layer:Ta (100). In addition, the numeric value in the above-mentioned parenthesis expresses thickness, and a unit is angstrom.

[0124] As conditions in a heat treatment process, 3 hours was first spent on the temperature up, then the temperature condition of 240 degrees was held for 3 hours, and 3 hours was further spent on the temperature fall again. In addition, the heat treatment degree of vacuum was set to 5x10 to 6 or less Torrs.

[0125] as shown in drawing 7 , when [and] an antiferromagnetism layer (PtMn alloy) is in the fixed magnetic layer bottom, and when [both] it is in the bottom, the amount of Pt(s) becomes large to about 50 at(s)% — alike —

following — an exchange anisotropy field — high — becoming — the amount of Pt(s) — about 50 — when it becomes more than at%, it turns out that the exchange anisotropy field is becoming small gradually.
[0126] In order to acquire the exchange anisotropy field more than 400 (Oe), when an antiferromagnetism layer (PtMn) is formed in the fixed magnetic layer bottom and an antiferromagnetism layer (PtMn) is formed in the fixed magnetic layer bottom for the amount of Pt(s) by 44 - 57at% of within the limits, it turns out that what is necessary is just to adjust the amount of Pt(s) to fitness by 47 - 57at% of within the limits.
[0127] Moreover, in order to acquire the exchange anisotropy field more than 600 (Oe), when an antiferromagnetism layer (PtMn) is formed in the fixed magnetic layer bottom and an antiferromagnetism layer (PtMn) is formed in the fixed magnetic layer bottom for the amount of Pt(s) by 46 - 55at% of within the limits, it turns out that what is necessary is just to adjust the amount of Pt(s) to fitness by 50 - 56at% of within the limits.
[0128] From the above experimental result, four kinds of multilayers were formed as an example which adjusted the presentation ratio of an antiferromagnetism layer (PtMn) to fitness, one kind of multilayers were formed as an example of a comparison, and it investigated about a stacking tendency, an exchange anisotropy field, etc. of each film. The experimental result is shown in Table 1.
[0129]
[Table 1]

表1

		膜構成	PtMn組成 (at%)	PtMn／Co−Fe 界面での格子整合	PtMnの{111}配向	強磁性層／Cu／強磁性層部分の{111}配向	240℃熱処理後のPtMnの規則化度	交換結合磁界, Hex (Oe)	抵抗変化率 (%)
実施例	①	基板／アルミナ／Ta(30Å)／PtMn(300Å)／Co−Fe(30Å)／Cu(22Å)／Co−Fe(10Å)／Ni−Fe(70Å)／Ta(50Å)	$Pt_{49}Mn_{51}$	なし	中	弱	○	770	6.7
	②	基板／アルミナ／PtMn(300Å)／Co(30Å)／Cu(24Å)／Ni−Fe(80Å) Ta(50Å)	$Pt_{50}Mn_{50}$	なし	弱	弱	○	730	4.5
	③	基板／アルミナ／Ta(50Å)／Ni−Fe(70Å)／Co−Fe(10Å)／Cu(28Å)／Co−Fe(30Å)／PtMn(300Å)／Ta(50Å)	$Pt_{51}Mn_{49}$	なし	弱	強	○	620	5.7
	④	基板／アルミナ／Ta(30Å)／PtMn(200Å)／Co−Fe(30Å)／Cu(22Å)／Co−Fe(10Å)／Ni−Fe(60Å)／Co−Fe(10Å)／Cu(22Å)／Co−Fe(30Å)／PtMn(200Å)／Ta(50Å)	$Pt_{49}Mn_{51}$	なし	中	弱	○	610	9.3
比較例	⑤	③と同一	$Pt_{44}Mn_{56}$	有り	強	強	×	40	0.2

The multilayers to example **-** are single spin bulb mold thin films, and the multilayers of example ** are dual spin bulb mold thin films. Moreover, the multilayers of example of comparison ** are the same film configurations as the multilayers of example **, and only the presentation ratios of an antiferromagnetism layer (PtMn) differ.

[0130] Moreover, although the laminating of Co-Fe and nickel-Fe is carried out to the multilayers of example ** on Cu (nonmagnetic conductive layer), the free magnetic layer consists of two-layer [this]. Although the laminating of

nickel-Fe and Co-Fe is similarly carried out to the multilayers of example ** under Cu (nonmagnetic conductive layer), the free magnetic layer consists of two-layer [this]. Moreover, although the laminating of Co-Fe, nickel-Fe, and Co-Fe is carried out to the multilayers of example ** between two Cu(s) (nonmagnetic conductive layer), the free magnetic layer consists of these three layers.

[0131] as shown in Table 1, in the multilayers to example **-**, the lattice matching in the interface of PtMn (antiferromagnetism layer) and CoFe (fixed magnetic layer) "is nothing" — receiving — the multilayers of example of comparison ** — the lattice matching in an interface — "— it is — " — it has become. Moreover, if the column of "whenever [regulation-ized / of PtMn after 240 degree-C heat treatment]" is seen, by the multilayers of example of comparison **, it is "x" to being "O" in the multilayers of example ** - **.

[0132] Furthermore, when the column of an "exchange anisotropy field" and "resistance rate of change" is seen, in the multilayers to example **-**, it turns out to having a large exchange anisotropy field and resistance rate of change that the exchange anisotropy field and resistance rate of change of multilayers of example of comparison ** are very small compared with the multilayers of example ** - **.

[0133] The above experimental result is related to the presentation ratio of a PtMn alloy. As shown in Table 1, the amount of Pt(s) of PtMn to example **-** is 49 - 51at% to the amount of Pt(s) of PtMn in example of comparison ** being 44at(s)%.

[0134] For this reason, when drawing 6 (before heat treatment) is referred to, it turns out that the lattice constant of PtMn of example of comparison ** is smaller than the lattice constant of PtMn to example **-**, and the difference of the lattice constant of PtMn (antiferromagnetism layer) and the lattice constant of Co-Fe (fixed magnetic layer) is [the direction of example of comparison **] small compared with example ** - **.

[0135] That is, in the multilayers of example of comparison **, the interface structure of PtMn and CoFe will tend to be in an adjustment condition, and, on the other hand, the interface structure of PtMn and CoFe will be easy to be in a disconformity condition in the phase before heat treatment by the multilayers to example **-**.

[0136] Before heat treatment, although the crystal structure of PtMn of example **-** and example of comparison ** serves as an irregular grid (face-centered cubic lattice), even if it heat-treats, the crystal structure of PtMn cannot metamorphose into a superlattice from an irregular grid, but regulation-ization is in the condition of not progressing at all, by example of comparison ** from which interface structure is in the adjustment condition.

[0137] On the other hand, in the multilayers of example ** from which interface structure is in the disconformity condition - **, by heat-treating, a part metamorphoses into a superlattice (face centred tetragonal lattice of LI0 mold) from an irregular grid, and the crystal structure of PtMn has become that to which regulation-ization fully advanced.

[0138] Drawing 8 is a high-resolution TEM photograph in which the interface structure of PtMn of example ** and CoFe after heat treatment is shown. As shown in drawing 8 , in the interface of PtMn and CoFe, it turns out that the direction of a list of the atom of PtMn and the direction of a list of the atom of CoFe are not in agreement, and it is in a disconformity condition.

[0139] On the other hand, drawing 9 is a high-resolution TEM photograph in which the interface structure of PtMn of example of comparison ** and CoFe after heat treatment is shown. As shown in drawing 9 , in the interface of PtMn and CoFe, it turns out that the direction of a list of the atom of PtMn and the direction of a list of the atom of CoFe are in agreement, and it is in an adjustment condition.

[0140] Moreover, drawing 10 is an experimental result after heat treatment to which drawing 11 measured whenever [regulation-ized / of PtMn / in / for whenever / regulation-ized / of PtMn in the multilayers of example ** / the multilayers of example of comparison **]. The experiment measured the include angle which two equivalent {111} sides in PtMn make, and asked for whenever [regulation-ized] from the include angle to make. In addition, the axis of abscissa shows the distance from the interface of PtMn and CoFe to the PtMn side.

[0141] As shown in drawing 10 , the measured value of the include angle which {111} sides make is scattered within the limits of about 65 to about 72 degrees, and it turns out that a part of irregular grid before heat treatment changes, and the crystal structure of PtMn serves as a superlattice.

[0142] On the other hand, in drawing 11 , the measured value of the include angle which {111} sides make has fallen within about 70 - about 71 range, and even if the crystal structure of PtMn heat-treats, it turns out that it has meant having maintained the condition of the irregular grid before heat treatment with as.

[0143] As mentioned above, in the multilayers of example ** - **, since interface structure can be made into a disconformity condition, therefore regulation-ization can be advanced to fitness by making the amount of Pt(s) of PtMn into 49 - 51at%, the exchange anisotropy field generated in the interface of PtMn and CoFe has the very large value so that it may understand, even if it sees drawing 7 .

[0144] On the other hand, in the multilayers of example of comparison **, since the amount of Pt(s) of PtMn is as low as 44at(s)%, the exchange anisotropy field which generates interface structure in the interface of PtMn and CoFe so that it may understand, even if it will be in an adjustment condition, regulation-ization does not progress to fitness but it sees drawing 7 will become a very small value. Moreover, in order to make interface structure of PtMn and CoFe into a disconformity condition, it is desirable to make the crystal orientation of PtMn and the crystal orientation of CoFe differ.

[0145] In addition, a little more than [of the amount of preferred orientation of the {111} sides shown in Table 1 / "a little more than"], "inside", and "weakness" express the priority amount of preferred orientation to the direction of a film surface. As shown in Table 1, both the amount of preferred orientation of the {111} sides of PtMn of example of comparison ** and the amount of preferred orientation of the {111} sides of CoFe (fixed magnetic layer) are ["a

little more than"].

[0146] If this refers to the film configuration of example **, NiFe, CoFe (free magnetic layer), Cu (nonmagnetic conductive layer), and CoFe (fixed magnetic layer) which were formed on Ta Since the difference of the lattice constant of CoFe (fixed magnetic layer) and the lattice constant of PtMn (antiferromagnetism layer) before heat treatment is small so that the amount of preferred orientation of {111} sides may become strong in response to the effect of Ta as a substrate layer and it may understand with reference to drawing 6 strongly Strongly in response to the fact that the effect of the amount of preferred orientation of the {111} sides of CoFe, priority orientation of the {111} sides of PtMn will be carried out in the direction of a film surface.

[0147] On the other hand, NiFe, CoFe (free magnetic layer), Cu (nonmagnetic conductive layer), and CoFe (fixed magnetic layer) which were formed on Ta in example ** Although the amount of preferred orientation of {111} sides becomes strong strongly in response to the fact that the effect of Ta as a substrate layer Since the difference of the lattice constant of CoFe (fixed magnetic layer) and the lattice constant of PtMn (antiferromagnetism layer) before heat treatment is large so that it may understand with reference to drawing 6 , the {111} sides of PtMn are seldom influenced of the crystal orientation of CoFe, but the amount of preferred orientation in the direction of a film surface is weak.

[0148] Moreover, in the case where it is example **** by which the laminating of the CoFe (fixed magnetic layer) is carried out on PtMn, if CoFe is formed on PtMn, the amount of preferred orientation of the {111} sides of CoFe will become weak, therefore the crystal orientation of PtMn and CoFe will be turned in the automatically different direction.

[0149] Next, in this invention, the antiferromagnetism layer was formed with the Pt-Mn-X' (X'=Ar) alloy, and it investigated about the relation between the amount of element X', and the lattice constant of a Pt-Mn-X' alloy. The film configurations used for the experiment are Si substrate / alumina / Ta(50) / Co90Fe10 (30) / Pt-Mn-X' (300) / Ta from the bottom (100). In addition, the numeric value in a parenthesis expresses thickness and a unit is angstrom.

[0150] In the sputtering system, membrane formation of an antiferromagnetism layer prepared three kinds of targets with which the rate of Pt and Mn is set to 6:4, 5:5, and 4:6, and it formed the Pt-Mn-X' (X'=Ar) alloy film by DC magnetron sputtering and the ion beam spatter, changing the introductory gas pressure of Ar which becomes element X' using each target. And it measured about the relation between the amount of X' (X'=Ar) occupied in the Pt-Mn-X' (X'=Ar) alloy film, and the lattice constant of Pt-Mn-X' (X'=Ar). The experimental result is shown in drawing 12 .

[0151] As shown in drawing 12 , when [of the presentation ratio of Pt and Mn] the amount of element X' (X'=Ar) becomes large in the case of either 6:4, 5:5 and 4:6 shows comparatively that the lattice constant of Pt-Mn-X' (X'=Ar) becomes large. In addition, the NiFe alloy which constitutes a fixed magnetic layer, a CoFe alloy, or Co As shown in drawing 12 , the range of a lattice constant is about 3.5 to 3.6. Moreover, although the amount of element X' (X'=Ar) is carried out to to about 4at% and the experiment is not tried about the case of a large content any more in this experiment, since it is a gas element, Ar from which this becomes element X' is because it is hard to contain Ar in the film, even if it raises gas pressure.

[0152] Next, the heat treatment process indicated below was given to the Pt-Mn-X' (X'=Ar) alloy film used for the above-mentioned experiment. As conditions in a heat treatment process, 3 hours was first spent on the temperature up, then, the temperature condition of 240 degrees was held for 3 hours, and 3 hours was further spent on the temperature fall. In addition, the heat treatment degree of vacuum was set to 5x10 to 6 or less Torrs.

[0153] Drawing 13 is a graph which shows the relation between the amount of element X' (X'=Ar) of the Pt-Mn-X' (X'=Ar) alloy film, and the magnitude of the switched connection field generated in the interface of an antiferromagnetism layer and a fixed magnetic layer by said heat treatment. As shown in drawing 13 , when the amount of element X' (X'=Ar) becomes large, it turns out that the switched connection field is large. That is, if element X' (X'=Ar) is added to PtMn, it is possible to acquire a large switched connection field compared with the case where element X' (X'=Ar) is not added.

[0154] Next, in this invention, using another element X', the antiferromagnetism layer was formed with the Pt-Mn-X' (X'=Mo) alloy, and it investigated about the relation between the amount of element X' (X'=Mo), and the lattice constant of the Pt-Mn-X' (X'=Mo) alloy film. The film configurations used for the experiment are Si substrate / alumina / Ta(50) / Co90Fe10 (30) / Pt-Mn-X' (300) / Ta from the bottom (100). In addition, the numeric value in a parenthesis expresses thickness and a unit is angstrom.

[0155] The compound-die target which stuck the chip of element X' (X'=Mo) on the target of PtMn was prepared for membrane formation of an antiferromagnetism layer, and changing the surface ratio of the chip occupied at a target, the amount of element X' (X'=Mo) occupied in the film was changed, and it measured about the relation between said amount of element X' (X'=Mo), and the lattice constant of a Pt-Mn-X' (X'=Mo) alloy. The experimental result is shown in drawing 14 .

[0156] It turns out that the lattice constant of Pt-Mn-X' (X'=Mo) becomes large, so that the concentration of element X' (X'=Mo) which the rate of the presentation ratio of Pt and Mn occupies in the film in one case of 6:4, 1:1, and 4:6 becomes large, as shown in drawing 14 . In addition, as shown in drawing 14 , the range of the NiFe alloy which constitutes a fixed magnetic layer, a CoFe alloy, or the lattice constant of Co is about 3.5 to 3.6.

[0157] Next, the heat treatment process indicated below was given to the Pt-Mn-X' (X'=Mo) alloy film used in the above-mentioned experiment. As conditions in a heat treatment process, 3 hours was first spent on the temperature up, then, the temperature condition of 240 degrees was held for 3 hours, and 3 hours was further spent

on the temperature fall. In addition, the heat treatment degree of vacuum was set to 5x10 to 6 or less Torrs.
[0158] Drawing 15 is a graph which shows the relation between the concentration of element X' (X'=Mo) of the Pt-Mn-X' (X'=Mo) alloy film, and the magnitude of the switched connection field generated in the interface of an antiferromagnetism layer and a fixed magnetic layer by said heat treatment. If the amount of element X' (X'=Mo) in the film becomes more than abbreviation 3at% even if the presentation ratio of Pt and Mn is which [of 6:4, 1:1, and 4:6] case comparatively as shown in drawing 15 , it turns out that a switched connection field falls gradually. especially — the amount of element X' (X'=Mo) in the film — about 10 — if it becomes more than at%, even if it is the case where the rate of the presentation ratio of Pt and Mn is 1:1, a switched connection field becomes very small and is not desirable.
[0159] By the way, at least, although it is a fitness element X' (X'=Mo) content, when it does not contain said element X' (X'=Mo), it is more desirable than the time of the amount of element X' (X'=Mo) being 0at% that a switched connection field becomes large. Comparatively, in the case of 6:4, if the amount of element X' (X'=Mo) is less than [abbreviation 1at%], a switched connection field will become large rather than the time of the amount of element X' (X'=Mo) being 0at% of the presentation ratio of Pt:Mn. Moreover, comparatively, in the case of 1:1, if the amount of element X' (X'=Mo) is less than [abbreviation 7at%], a switched connection field will become large rather than the time of the amount of element X' (X'=Mo) being 0at% of the presentation ratio of Pt:Mn. Furthermore, comparatively, in the case of 4:6, if the amount of element X' (X'=Mo) is less than [abbreviation 10at%], a switched connection field will become large rather than the time of the amount of element X' (X'=Mo) being 0at% of the presentation ratio of Pt:Mn.
[0160] next — although it is the minimum of a fitness element X' (X'=Mo) content — the presentation ratio of Pt:Mn — since the switched connection field became the largest comparatively when the amount of element X' (X'=Mo) became about 0.5 at(s)% in the case of 6:4, by this invention, the amount of element X' (X'=Mo) set up 0.2at(s)% smaller than 0.5at% as a minimum there.
[0161] By this invention, the desirable range of the presentation ratio of element X' was set to 0.2 to 10 at at% from the above experimental result. Moreover, the more desirable range was set to 0.5 to 5 at at%. In addition, the desirable presentation range of above-mentioned element X' is the case where Mn is set up within the limits of Pt (= element X) and4:6 to 6:4.
[0162]
[Effect of the Invention] It sets on the switched connection film which consists of an antiferromagnetism layer and a ferromagnetic layer according to this invention explained in full detail above, and is said antiferromagnetism layer X-Mn (however, X) When forming, the presentation ratio of said antiferromagnetism layer is adjusted to fitness. the inside of Pt, Pd, Ir, Rh, Ru, and Os — any one sort or two sorts or more of elements — it is — Since interface structure of said antiferromagnetism layer and ferromagnetic layer (for example, NiFe alloy) is made into the disconformity condition, it is possible to acquire a larger exchange anisotropy field.
[0163] Or at this invention, it is element X' (however, X'). Ne, Ar, Kr, Xe, Be, B, C, N, Mg, aluminum, Si, P, Ti, V, Cr, Fe, Co, nickel, Cu, Zn, Ga, germanium, Zr, Nb, Mo, Ag, Cd, Ir, Sn, Hf, Ta, W, Re, Au, Pb, and the inside of rare earth elements — one sort or two sorts or more of elements — it is — by making it dissolve with an invasion mold or a permutation mold in the X-Mn alloy film It is possible for the interface structure of said antiferromagnetism layer and ferromagnetic layer (for example, NiFe alloy) to change into a disconformity condition, and to acquire a larger exchange anisotropy field.
[0164] moreover, the phase which heat-treated — setting — a part of [at least] crystal structures of said antiferromagnetism layer — the face centred tetragonal lattice (superlattice) of L10 mold — becoming — **** — moreover — the ratio of the lattice constants a and c of said antiferromagnetism layer — it is desirable that c/a is within the limits of 0.93-0.99 at the point that a larger exchange anisotropy field can be acquired. Furthermore, it is desirable that the crystal orientation of said antiferromagnetism layer and ferromagnetic layer in an interface differs at the point which is easy to change interface structure into a disconformity condition.
[0165] As mentioned above, by applying the switched connection film with which interface structure is in the disconformity condition to a magneto-resistive effect component, the resistance rate of change of said magneto-resistive effect component layer can be raised, and it is possible to raise reproducing characteristics.

[Translation done.]

DESCRIPTION OF DRAWINGS

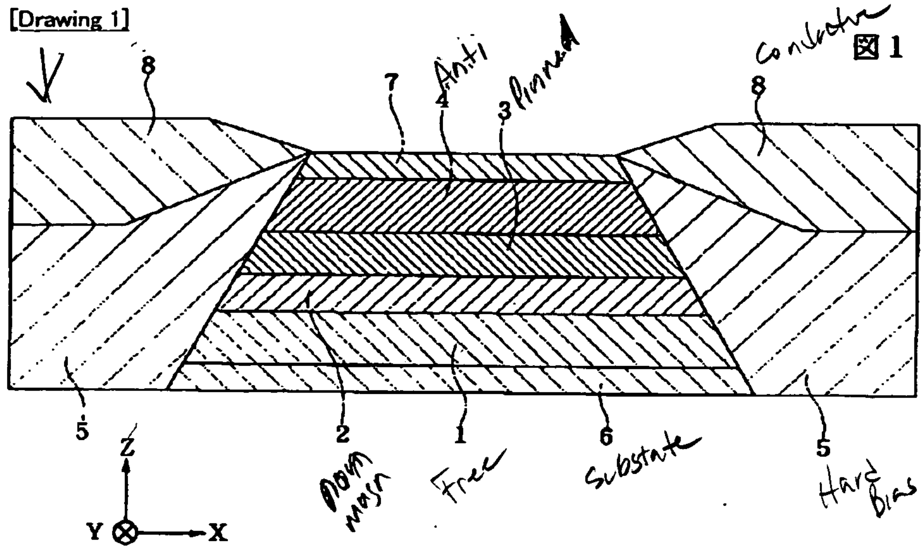
[Brief Description of the Drawings]
[Drawing 1] The sectional view which looked at the structure of the single spin bulb mold thin film of the 1st operation gestalt of this invention from the ABS side side.
[Drawing 2] The sectional view which looked at the structure of the single spin bulb mold thin film of the 2nd operation gestalt of this invention from the ABS side side.
[Drawing 3] The sectional view which looked at the structure of the dual spin bulb mold thin film of the 3rd operation gestalt of this invention from the ABS side side.
[Drawing 4] The sectional view which looked at the structure of the AMR mold thin film of the 4th operation gestalt of this invention from the ABS side side.
[Drawing 5] The sectional view which looked at the thin film magnetic head in this invention from the opposed face side with a record medium.
[Drawing 6] The graph which shows the relation between the amount of Pt(s) before heat treatment at the time of forming an antiferromagnetism layer by PtMn, and the lattice constant of said antiferromagnetism layer.
[Drawing 7] The graph which shows the relation of the amount of Pt(s) and exchange anisotropy field at the time of forming an antiferromagnetism layer by PtMn.
[Drawing 8] The high-resolution TEM photograph of the multilayers of example ** shown in Table 1.
[Drawing 9] The high-resolution TEM photograph of the multilayers of example of comparison ** shown in Table 1.
[Drawing 10] The graph which shows whenever [regulation-ized / of PtMn (antiferromagnetism layer) in the multilayers of example ** shown in Table 1].
[Drawing 11] The graph which shows whenever [regulation-ized / of PtMn (antiferromagnetism layer) in the multilayers of example ** shown in Table 1].
[Drawing 12] The graph which shows the relation between the amount of element X' (X'=Ar) at the time of forming an antiferromagnetism layer by Pt-Mn-X' (X'=Ar), and the lattice constant of said antiferromagnetism layer.
[Drawing 13] The graph which shows the relation of the amount of element X' (X'=Ar) and switched connection field at the time of forming an antiferromagnetism layer by Pt-Mn-X' (X'=Ar).
[Drawing 14] The graph which shows the relation between the amount of element X' (X'=Mo) at the time of forming an antiferromagnetism layer by Pt-Mn-X' (X'=Mo), and the lattice constant of said antiferromagnetism layer.
[Drawing 15] The graph which shows the relation of the amount of element X' (X'=Mo) and switched connection field at the time of forming an antiferromagnetism layer by Pt-Mn-X' (X'=Mo).

[Description of Notations]
1 Free Magnetic Layer
2 Nonmagnetic Conductive Layer
3 Fixed Magnetic Layer
4 Antiferromagnetism Layer
5 Hard Bias Layer
6 Substrate Layer
7 Protective Layer
8 Conductive Layer
9 Exchange Bias Layer
10 Soft Magnetism Layer (SAL Layer)
11 Non-magnetic Layer (SHUNT Layer)
12 Magnetic-Reluctance Layer (MR Layer)
20 Lower Shielding Layer
21 Lower Gap Layer
22 Magneto-resistive Effect Component Layer
23 Up Gap Layer
24 Up Shielding Layer

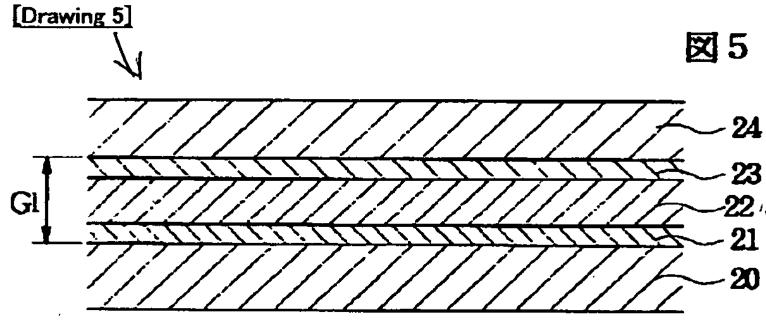
[Translation done.]

DRAWINGS

[Drawing 1]

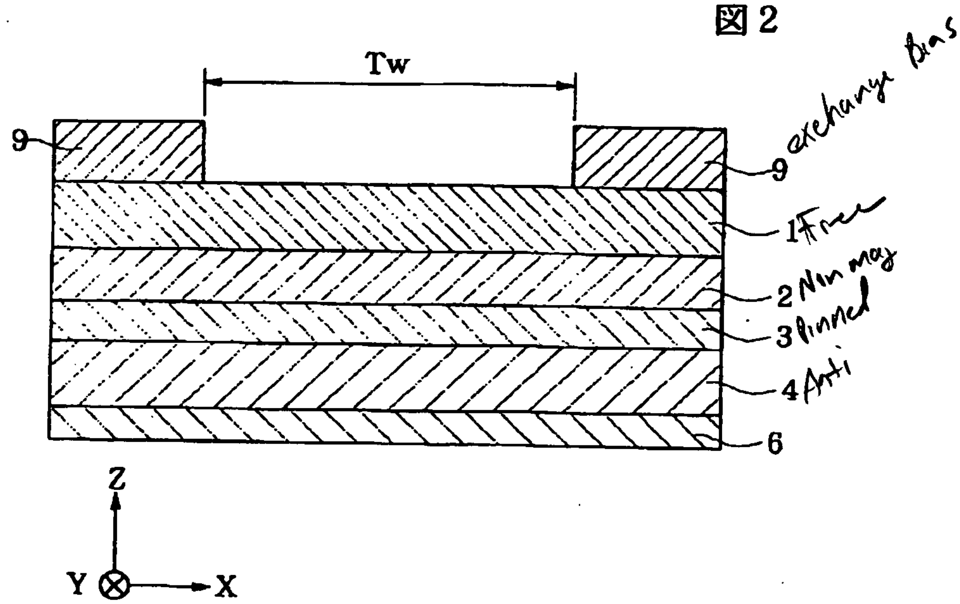


[Drawing 5]



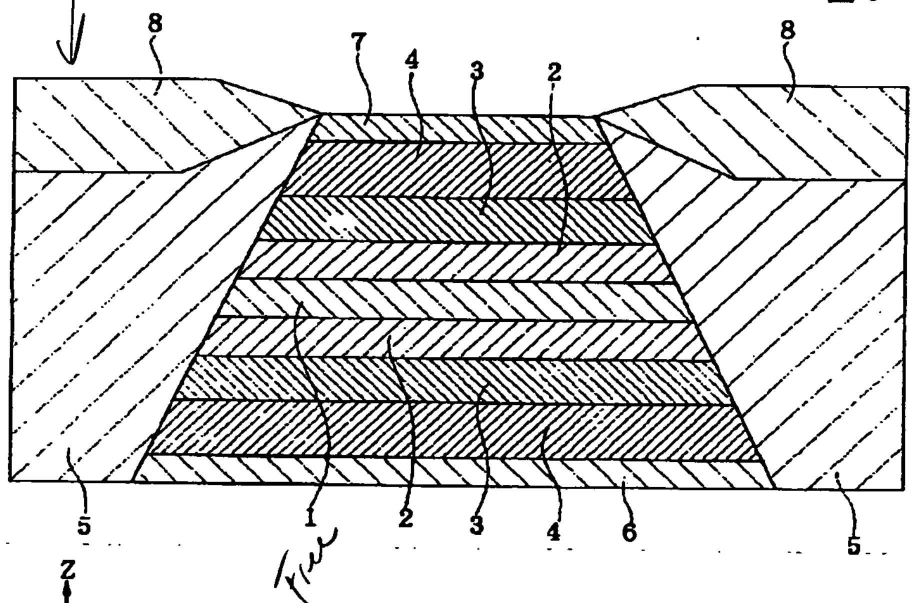
[Drawing 2]

図 2



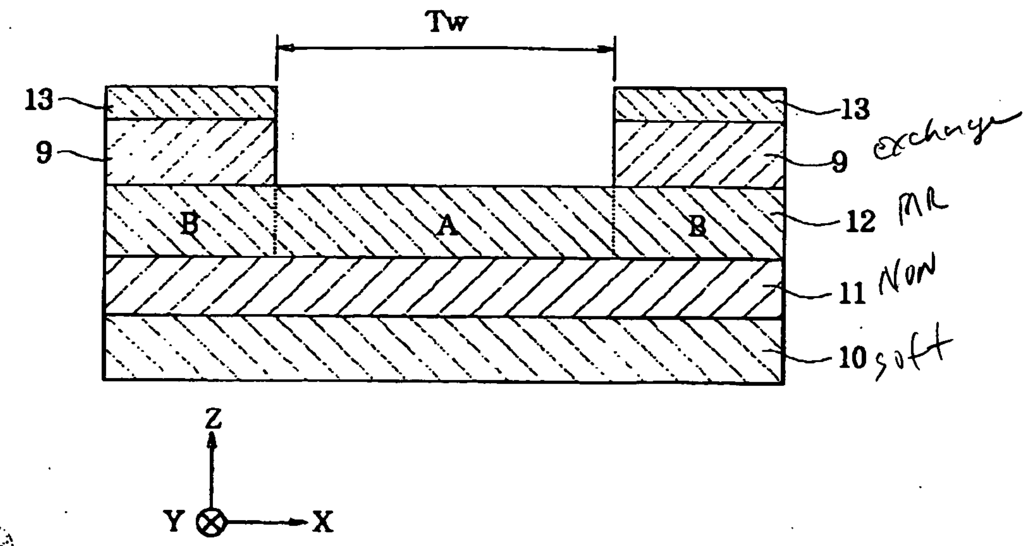
[Drawing 3]

図 3



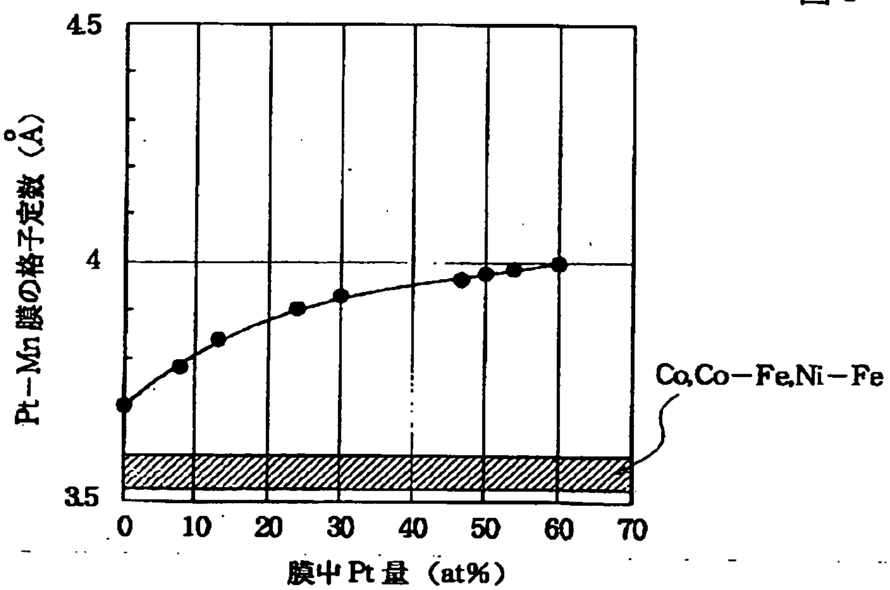
[Drawing 4]

図 4



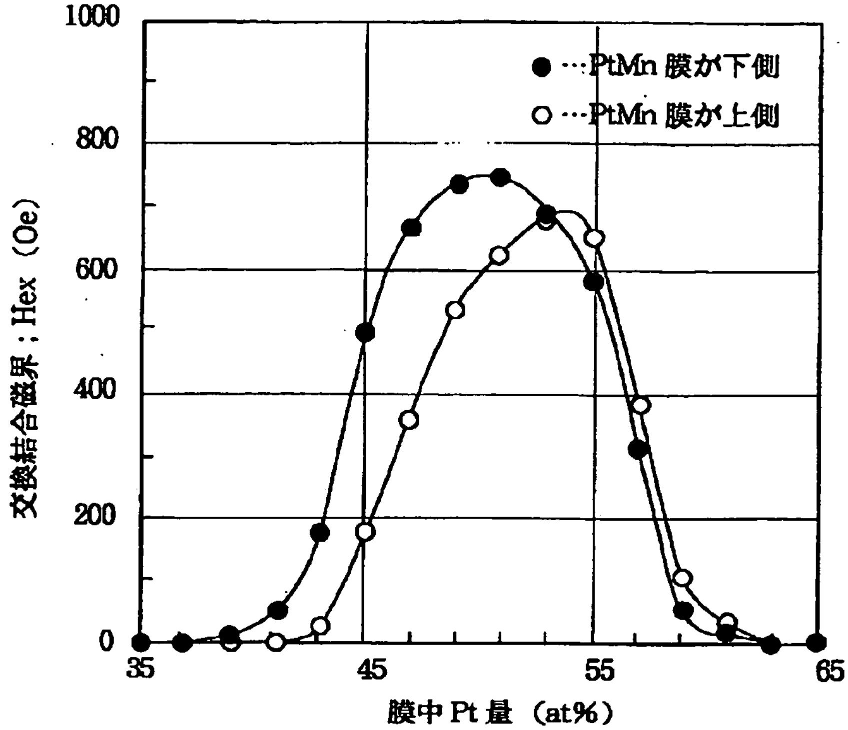
[Drawing 6]

図 6



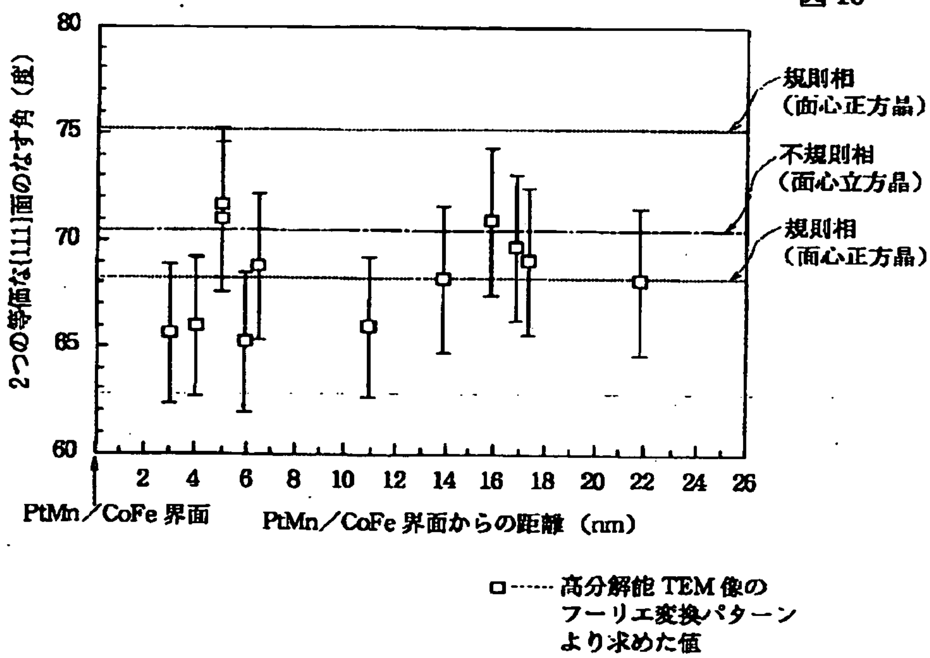
[Drawing 7]

図7



[Drawing 10]

図 10



[Drawing 8]

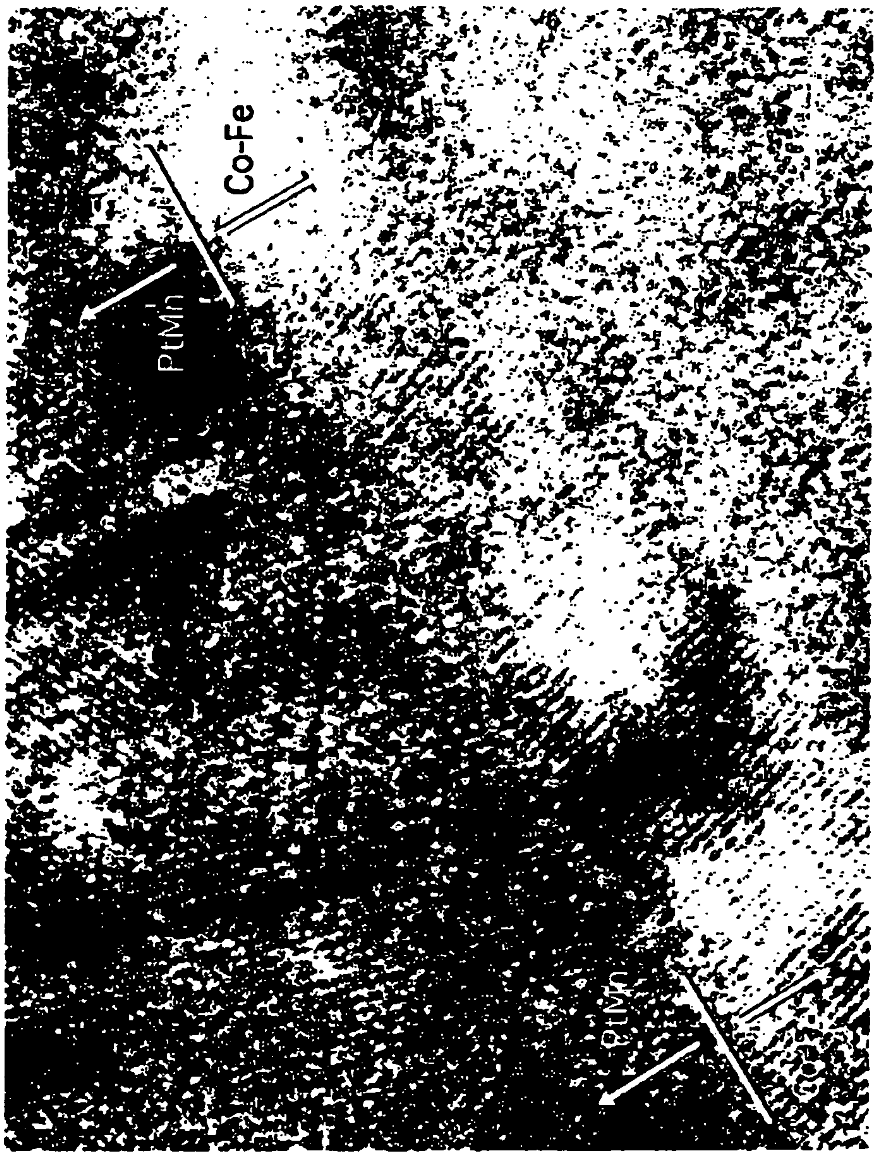


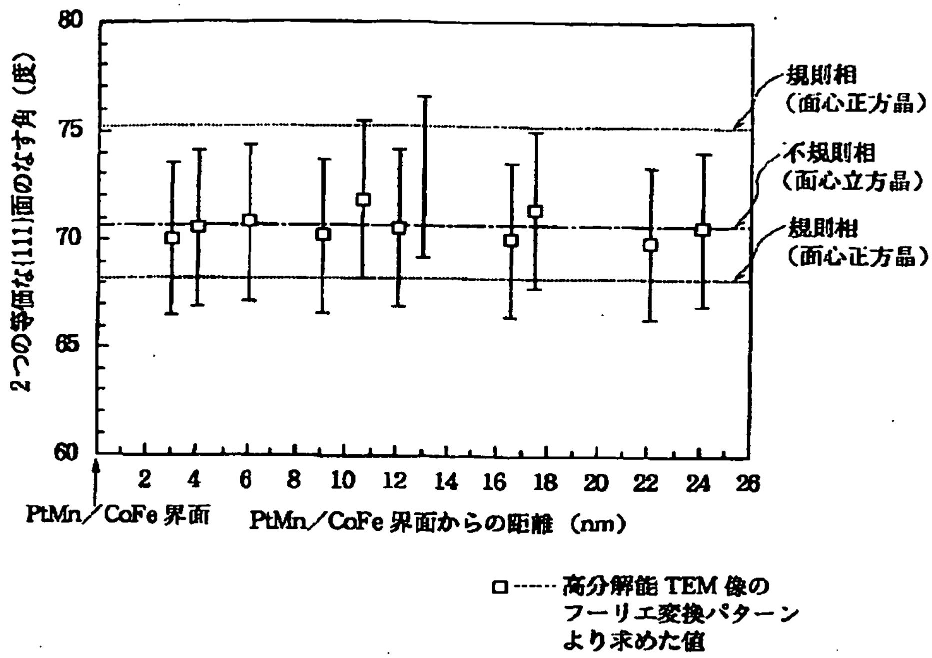
図8

[Drawing 9]

図9

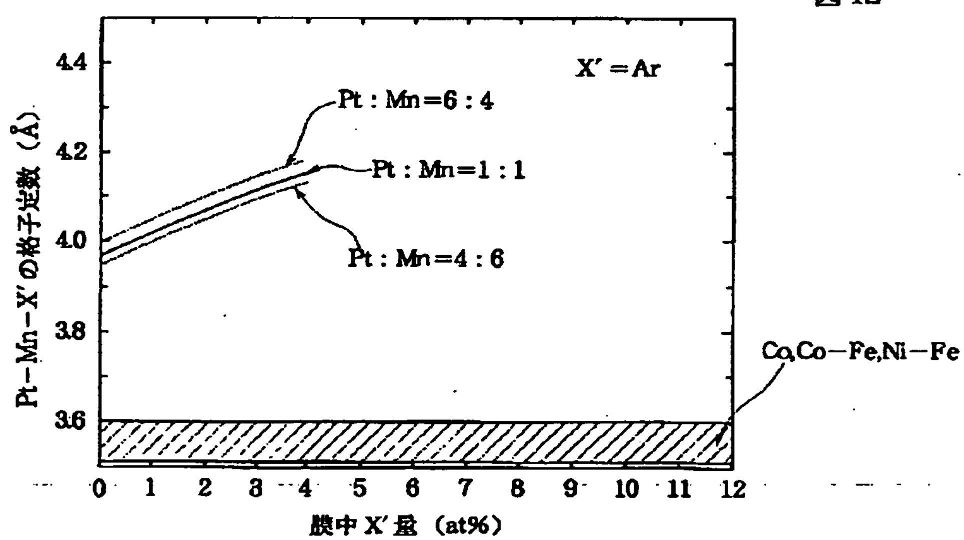
[Drawing 11]

図 11



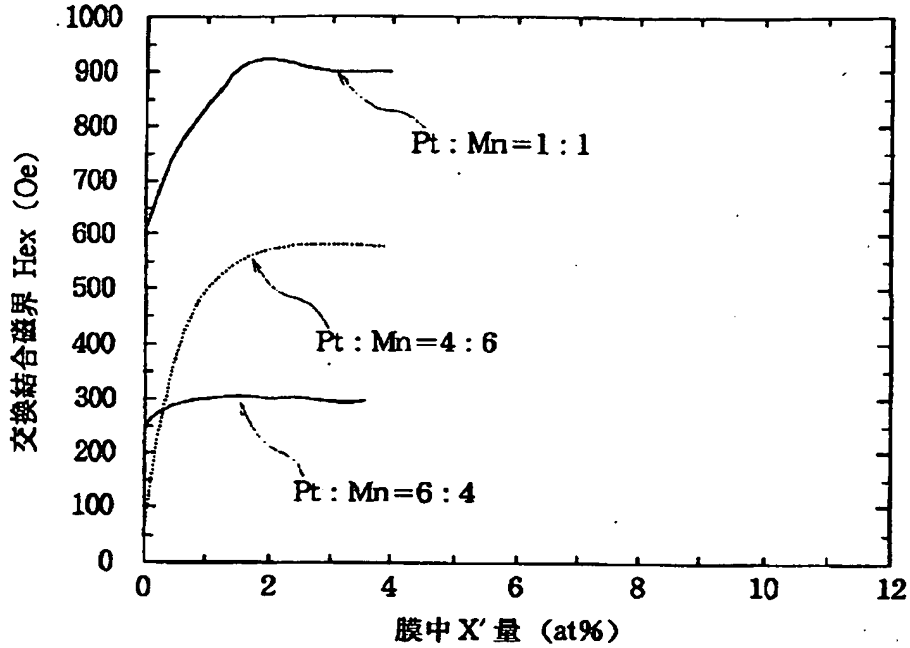
[Drawing 12]

図 12



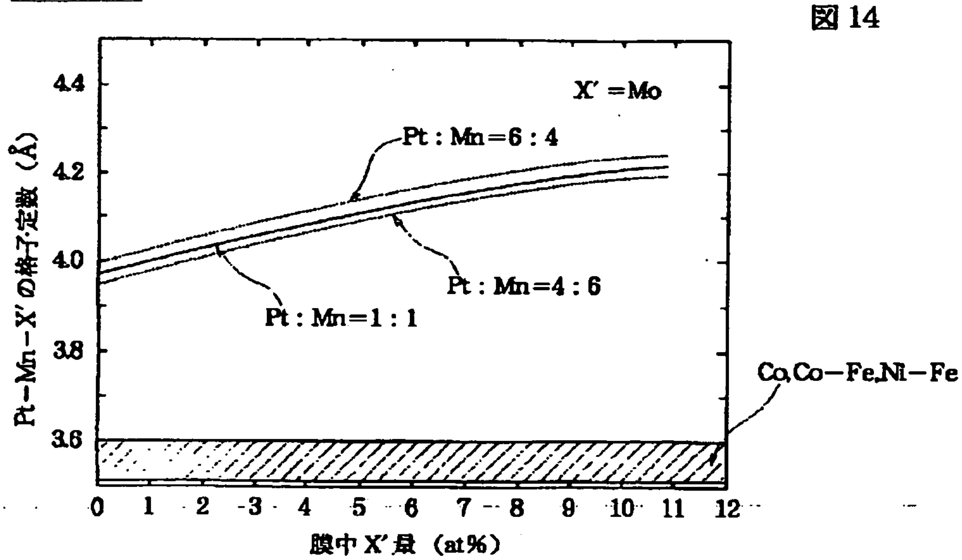
[Drawing 13]

図 13



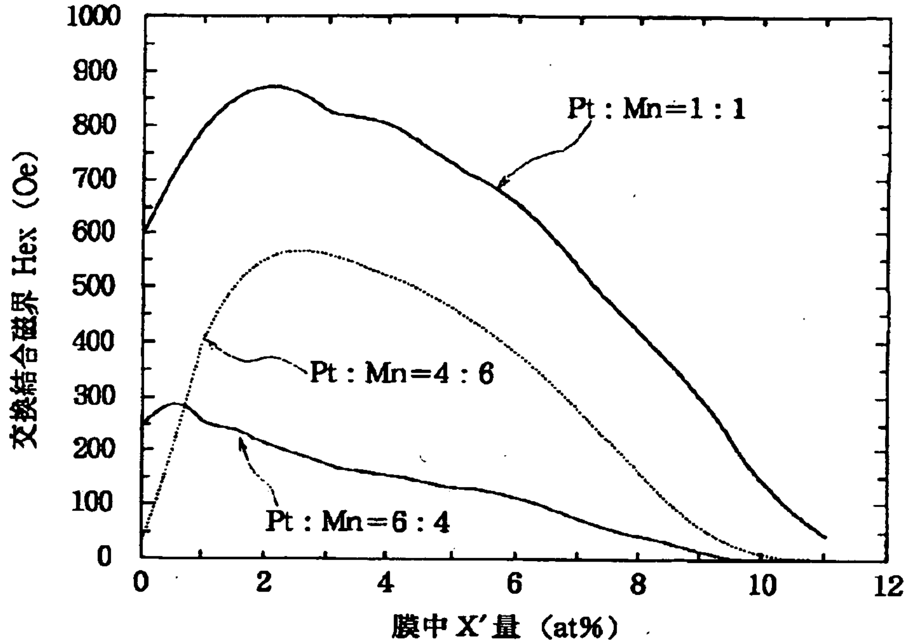
[Drawing 14]

図 14



[Drawing 15]

図 15



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最終頁に続く

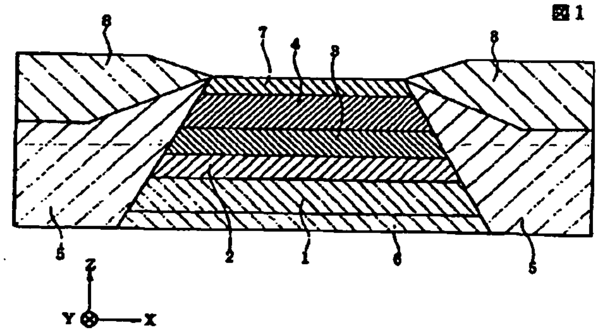
(54)【発明の名称】　交換結合膜と、この交換結合膜を用いた磁気抵抗効果素子、ならびに、前記磁気抵抗効果素子を用いた薄膜磁気ヘッド

(57)【要約】

【目的】　従来、反強磁性層として使用されていたＮｉＭｎ合金の場合、固定磁性層（例えばＮｉＦｅ合金）との界面構造を整合状態としておいても、適性な交換異方性磁界を得ることができるが、ＮｉＭｎ合金よりも優れた反強磁性材料である白金族元素を用いたＸ－Ｍｎ合金の場合、固定磁性層との界面構造を整合状態とすると、交換異方性磁界を得ることができないという問題点があった。

【構成】　反強磁性層４はＸ－Ｍｎ（Ｘは白金族元素）で形成され、Ｘの組成比が適性に調節されることにより、固定磁性層３との界面構造は非整合状態にされている。従って熱処理を施すことにより、前記反強磁性層４の結晶構造が変態し、大きな交換異方性磁界を得ることができるので、従来に比べてより再生特性を向上させることが可能である。

図１



1

【特許請求の範囲】

【請求項１】 反強磁性層と強磁性層とが接して形成され、熱処理が施されることにより、前記反強磁性層と強磁性層との界面にて交換異方性磁界が発生し、前記強磁性層の磁化方向が一定方向に固定される交換結合膜において、前記反強磁性層は、少なくとも元素Ｘ（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）とＭｎとを含有する反強磁性材料で形成され、前記反強磁性層と強磁性層との界面構造が、非整合状態にあることを特徴とする交換結合膜。

【請求項２】 熱処理後における前記反強磁性層の少なくとも一部の結晶構造が、Ｌ１$_0$型の面心正方規則格子となる請求項１記載の交換結合膜。

【請求項３】 前記反強磁性層と強磁性層との界面にて、前記反強磁性層および強磁性層の結晶配向が異なっている請求項１または２に記載の交換結合膜。

【請求項４】 前記強磁性層の｛１１１｝面が、前記反強磁性層との界面に平行な方向に優先配向するのに対し、前記反強磁性層の｛１１１｝面の配向度は、前記強磁性層の配向度よりも小さいか、あるいは無配向となっている請求項３記載の交換結合膜。

【請求項５】 前記反強磁性層の｛１１１｝面が、前記強磁性層との界面に平行な方向に優先配向するのに対し、前記強磁性層の｛１１１｝面の配向度は、前記反強磁性層の配向度よりも小さいか、あるいは無配向となっている請求項３記載の交換結合膜。

【請求項６】 前記反強磁性層と強磁性層との界面に平行な方向への、前記反強磁性層の｛１１１｝面の配向度、および前記強磁性層の｛１１１｝面の配向度は共に小さくなっているか、あるいは無配向となっており、前記｛１１１｝面以外の結晶面が、界面に平行な方向へ優先配向されて、反強磁性層と強磁性層の結晶配向が異なる請求項３記載の交換結合膜。

【請求項７】 前記反強磁性層はＸ－Ｍｎ合金で形成され、元素Ｘは、Ｐｔである請求項１ないし６のいずれかに記載の交換結合膜。

【請求項８】 前記反強磁性層はＰｔＭｎ合金で形成され、熱処理後における前記反強磁性層の格子定数ａ，ｃの比ｃ／ａは、０．９３～０．９９の範囲内である請求項７記載の交換結合膜。

【請求項９】 前記反強磁性層は、Ｘ－Ｍｎ－Ｘ′合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成され、前記Ｘ－Ｍｎ－Ｘ′合金は、元素ＸとＭｎとで構成される空間格子の隙間に元素Ｘ′が侵入した侵入型固溶体であり、あるいは、元素ＸとＭｎとで構成される結晶格子の格子点の一部が、元素Ｘ′に置換された置換型固溶体である請求項１ないし６のいずれかに記載の交換結合膜。

2

【請求項１０】 前記反強磁性層として用いられるＸ－Ｍｎ－Ｘ′合金の元素ＸはＰｔである請求項９記載の交換結合膜。

【請求項１１】 前記元素Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である請求項９または１０に記載の交換結合膜。

【請求項１２】 前記元素Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅのうち１種または２種以上の元素である請求項１１記載の交換結合膜。

【請求項１３】 前記元素Ｘ′の組成比はａｔ％で、０．２～１０の範囲内である請求項９ないし１２のいずれかに記載の交換結合膜。

【請求項１４】 前記元素Ｘ′の組成比はａｔ％で、０．５～５の範囲内である請求項１３記載の交換結合膜。

【請求項１５】 元素ＸとＭｎとの組成比の割合Ｘ：Ｍｎは、４：６～６：４の範囲内である請求項１３または１４に記載の交換結合膜。

【請求項１６】 前記反強磁性層として用いられるＸ－Ｍｎ－Ｘ′合金は、スパッタ法により形成される請求項９ないし１５のいずれかに記載の交換結合膜。

【請求項１７】 前記反強磁性層が、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成され、前記反強磁性層が強磁性層の上に形成されており、Ｘ－Ｍｎ合金のＸの組成比はａｔ％で、４７～５７の範囲内である請求項１、７、８のいずれかに記載の交換結合膜。

【請求項１８】 前記反強磁性層が、Ｘ－Ｍｎ－Ｘ′合金（ただし、Ｘは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素であり、Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成され、前記反強磁性層が強磁性層の上に形成されており、Ｘ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、４７～５７の範囲内である請求項１３ないし１５のいずれかに記載の交換結合膜。

【請求項１９】 Ｘ－Ｍｎ合金のＸの組成比、あるいはＸ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、５０～５６の範囲内である請求項１７または１８記載の交換結合膜。

【請求項２０】 前記反強磁性層が、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうち

いずれか１種または２種以上の元素である）で形成され、前記反強磁性層が強磁性層の下に形成されており、Ｘ－Ｍｎ合金のＸの組成比はａｔ％で、４４～５７の範囲内である請求項１、７、８のいずれかに記載の交換結合膜。

【請求項２１】　前記反強磁性層が、Ｘ－Ｍｎ－Ｘ′合金（ただしＸ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成され、前記反強磁性層が強磁性層の下に形成されており、Ｘ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、４４～５７の範囲内である請求項１３ないし１５のいずれかに記載の交換結合膜。

【請求項２２】　Ｘ－Ｍｎ合金のＸの組成比、あるいはＸ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、４６～５５の範囲内である請求項２０または２１記載の交換結合膜。

【請求項２３】　反強磁性層と、この反強磁性層と接して形成され、前記反強磁性層との交換異方性磁界により磁化方向が固定される固定磁性層と、前記固定磁性層に非磁性導電層を介して形成されたフリー磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向へ揃えるバイアス層と、固定磁性層と非磁性導電層とフリー磁性層に検出電流を与える導電層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、請求項１ないし請求項２２のいずれかに記載された交換結合膜により形成されていることを特徴とする磁気抵抗効果素子。

【請求項２４】　前記フリー磁性層の上側または下側に、トラック幅Ｔｗの間隔を空けて反強磁性層が積層され、前記反強磁性層とフリー磁性層とが、請求項１ないし請求項２２のいずれかに記載された交換結合膜により形成されている請求項２３記載の磁気抵抗効果素子。

【請求項２５】　フリー磁性層の上下に積層された非磁性導電層と、一方の前記非磁性導電層の上および他方の非磁性導電層の下に位置する固定磁性層と、一方の前記固定磁性層の上および他方の固定磁性層の下に位置して、交換異方性磁界によりそれぞれの固定磁性層の磁化方向を一定の方向に固定する反強磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向に揃えるバイアス層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、請求項１ないし請求項２２のいずれかに記載された交換結合膜により形成されていることを特徴とする磁気抵抗効果素子。

【請求項２６】　非磁性層を介して重ねられた磁気抵抗層と軟磁性層とを有し、前記磁気抵抗層の上側あるいは下側にトラック幅Ｔｗの間隔を空けて反強磁性層が形成され、前記反強磁性層と磁気抵抗層とが、請求項１ないし請求項２２のいずれかに記載された交換結合膜により形成されていることを特徴とする磁気抵抗効果素子。

【請求項２７】　請求項２３ないし２６のいずれかに記載された磁気抵抗効果素子の上下にギャップ層を介してシールド層が形成されていることを特徴とする薄膜磁気ヘッド。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、反強磁性層と強磁性層とから成り、前記反強磁性層と強磁性層との界面にて発生する交換異方性磁界により、前記強磁性層の磁化方向が一定の方向に固定される交換結合膜に係り、特に前記反強磁性層が元素Ｘ（Ｐｔ，Ｐｄ等）とＭｎとを含有する反強磁性材料で形成された場合、より大きい交換異方性磁界を得られるようにした交換結合膜およびこの交換結合膜を用いた磁気抵抗効果素子（スピンバルブ型薄膜素子、ＡＭＲ素子）に関する。

【０００２】

【従来の技術】スピンバルブ型薄膜素子は、巨大磁気抵抗効果を利用したＧＭＲ（giant magnetoresistive）素子の１種であり、ハードディスクなどの記録媒体からの記録磁界を検出するものである。このスピンバルブ型薄膜素子は、ＧＭＲ素子の中でも比較的構造が単純で、しかも弱い磁界で抵抗が変化するなど、いくつかの優れた点を有している。

【０００３】前記スピンバルブ型薄膜素子は、最も単純な構造で、反強磁性層、固定磁性層、非磁性導電層およびフリー磁性層から成る。前記反強磁性層と固定磁性層とは接して形成され、前記反強磁性層と固定磁性層との界面にて発生する交換異方性磁界により、前記固定磁性層の磁化方向は一定方向に単磁区化され固定される。フリー磁性層の磁化は、その両側に形成されたバイアス層により、前記固定磁性層の磁化方向と交叉する方向に揃えられる。

【０００４】前記反強磁性層にはＦｅ－Ｍｎ（鉄－マンガン）合金膜、またはＮｉ－Ｍｎ（ニッケル－マンガン）合金膜、固定磁性層及びフリー磁性層にはＮｉ－Ｆｅ（ニッケル－鉄）合金膜、非磁性導電層３にはＣｕ（銅）膜、またバイアス層にはＣｏ－Ｐｔ（コバルト－白金）合金膜などが一般的に使用されている。

【０００５】このスピンバルブ型薄膜素子では、ハードディスクなどの記録媒体からの漏れ磁界により、前記フリー磁性層の磁化方向が変動すると、固定磁性層の固定磁化方向との関係で電気抵抗が変化し、この電気抵抗値の変化に基づく電圧変化により、記録媒体からの洩れ磁界が検出される。

【０００６】ところで、前述したように、反強磁性層には、Ｆｅ－Ｍｎ合金膜やＮｉ－Ｍｎ合金膜が用いられるが、Ｆｅ－Ｍｎ合金膜は、耐食性が低く、また交換異方

性磁界が小さく、さらにブロッキング温度が150℃程度と低くなっている。ブロッキング温度が低いことで、ヘッドの製造工程中やヘッド動作中における素子温度の上昇により、交換異方性磁界が消失してしまうという問題が発生する。これに対し、Ni－Mn合金膜は、Fe－Mn合金膜に比べて、交換異方性磁界が比較的大きく、しかもブロッキング温度が約300℃と高い。従って反強磁性層には、Fe－Mn合金膜よりもNi－Mn合金膜を用いる方が好ましい。

【0007】また、B. Y. Wong, C. Mitsumata, S. Prakash, D. E. Laughlin, and T. Kobayashi：Journal of Applied Phsysics, vol. 79, No10, p. 7896－p. 7904（1996）には、Ni－Mn合金膜を反強磁性層として用いた場合における前記反強磁性層と固定磁性層（NiFe合金膜）との界面構造について報告されている。

【0008】この論文には、「NiFeとNiMnの両方の{111}面が膜面と平行となるように、NiFe／NiMn界面での結晶整合状態を保って成長している。界面での整合歪みは、膜面と平行な面を双晶面とする双晶が多数導入されることにより緩和されている。ただし、残存している界面歪みにより、界面近くでのNiMnの規則化は低く抑制され、界面から離れた場所では規則化度が高くなっている。」と記載されている。

【0009】なお、整合とは、界面における反強磁性層と固定磁性層との原子が、1対1で対応する状態のことをいい、逆に非整合とは、界面における反強磁性層と固定磁性層との原子が一対の位置関係にない状態のことをいう。

【0010】NiMn合金で反強磁性層が形成される場合、熱処理が施されることにより、NiMn合金と固定磁性層との界面に、交換異方性磁界が発生するが、これは熱処理が施されることにより、NiMn合金が不規則格子から規則格子に変態することによる。

【0011】熱処理が施される前では、NiMn合金の結晶構造は、Ni，Mn原子の配列順序が不規則な面心立方格子（以下、不規則格子という）であるが、熱処理が施されると、結晶構造は、面心立方格子から面心正方格子に変態し、しかも原子位置が規則化（以下規則格子という）する。なお、結晶構造が完全に規則格子となった場合におけるNi－Mn合金膜の格子定数a，cの比c／aは、0．942である。

【0012】このように、完全に規則格子となったNiMn合金膜の格子定数比c／aは、比較的1に近い値であるため、不規則格子から規則格子に変態する時に生じる界面での格子歪みは、比較的小さくなっており、従ってNiMn合金膜と固定磁性層との界面構造が整合状態にあっても、熱処理が施されることにより、NiMn合金が不規則格子から規則格子に変態し、交換異方性磁界が発生する。なお前述した論文に記載されているように、界面における格子歪みは、双晶によりある程度緩和されている。

【0013】

【発明が解決しようとする課題】前述したように、NiMn合金は、比較的交換異方性磁界が大きく、またブロッキング温度も約300℃と高くなっており、従来のFeMn合金に比べて優れた特性を有しているが、耐食性に関しては、FeMn合金と同じ様に、充分であるとはいえなかった。

【0014】そこで最近では、耐食性に優れ、しかもNiMn合金よりも大きい交換異方性磁界を発生し、高いブロッキング温度を有する反強磁性材料として、白金族元素を用いたX－Mn合金（X＝Pt，Pd，Ir，Rh，Ru，Os）が注目を浴びている。白金族元素を含有するX－Mn合金を反強磁性層として用いれば、従来に比べて再生出力を向上させることができ、またヘッド駆動動作時における素子温度の上昇により、交換異方性磁界が消滅し再生特性が低下するといった不具合も生じにくくなる。

【0015】ところで、この白金族元素を含有するX－Mn合金を反強磁性層として用いた場合、交換異方性磁界を発生させるには、NiMn合金を反強磁性層として用いた場合と同様に、成膜後熱処理を施す必要がある。NiMn合金の場合、前述した文献によれば、固定磁性層（NiFe合金）との界面構造は整合状態となっていると記載されているが、X－Mn合金（Xは白金族元素）の場合も同じ様に、固定磁性層との界面構造を整合状態としておくと、熱処理を施しても交換異方性磁界がほとんど発生しないことがわかった。

【0016】本発明は上記従来の課題を解決するためのものであり、反強磁性層として、元素X（Xは白金族元素）とMnとを含有する反強磁性材料を用いた場合、大きい交換異方性磁界を発生することができるようにした交換結合膜、およびこの交換結合膜を用いた磁気抵抗効果素子に関する。

【0017】

【課題を解決するための手段】本発明は、反強磁性層と強磁性層とが接して形成され、熱処理が施されることにより、前記反強磁性層と強磁性層との界面にて交換異方性磁界が発生し、前記強磁性層の磁化方向が一定方向に固定される交換結合膜において、前記反強磁性層は、少なくとも元素X（ただしXは、Pt，Pd，Ir，Rh，Ru，Osのうちいずれか1種または2種以上の元素である）とMnとを含有する反強磁性材料で形成され、前記反強磁性層と強磁性層との界面構造が、非整合状態にあることを特徴とするものである。

【0018】また、熱処理後における前記反強磁性層の少なくとも一部の結晶構造が、$L1_0$型の面心正方規則格子となっていることが好ましい。さらに本発明では、

前記反強磁性層と強磁性層との界面にて、前記反強磁性層および強磁性層の結晶配向が異なっていることが好ましい。

【0019】本発明では、前記強磁性層の｛111｝面が、前記反強磁性層との界面に平行な方向に優先配向するのに対し、前記反強磁性層の｛111｝面の配向度は、前記強磁性層の配向度よりも小さいか、あるいは無配向となっている。

【0020】あるいは、前記反強磁性層の｛111｝面が、前記強磁性層との界面に平行な方向に優先配向するのに対し、前記強磁性層の｛111｝面の配向度は、前記反強磁性層の配向度よりも小さいか、あるいは無配向となっている。

【0021】あるいは、前記反強磁性層と強磁性層との界面に平行な方向への、前記反強磁性層の｛111｝面の配向度、および前記強磁性層の｛111｝面の配向度は共に小さくなっているか、あるいは無配向となっており、前記｛111｝面以外の結晶面が、界面に平行な方向へ優先配向されて、反強磁性層と強磁性層の結晶配向が異なっている。

【0022】また本発明では、前記反強磁性層はＸ－Ｍｎ合金で形成され、元素Ｘは、Ｐｔであることが好ましい。さらに、前記反強磁性層がＰｔＭｎ合金で形成される場合、熱処理後における前記反強磁性層の格子定数ａ，ｃの比ｃ／ａは、０．９３～０．９９の範囲内であることが好ましい。

【0023】または本発明では、前記反強磁性層は、Ｘ－Ｍｎ－Ｘ′合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成され、前記Ｘ－Ｍｎ－Ｘ′合金は、元素ＸとＭｎとで構成される空間格子の隙間に元素Ｘ′が侵入した侵入型固溶体であり、あるいは、元素ＸとＭｎとで構成される結晶格子の格子点の一部が、元素Ｘ′に置換された置換型固溶体である。特に、前記反強磁性層として用いられるＸ－Ｍｎ－Ｘ′合金の元素ＸはＰｔである、すなわち前記反強磁性層は、Ｐｔ－Ｍｎ－Ｘ′合金により形成されていることが好ましい。

【0024】なお本発明では、前記反強磁性層として用いられるＸ－Ｍｎ－Ｘ′合金の元素Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素であることが好ましく、より好ましくは、前記元素Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅのうち１種または２種以上の元素である。

【0025】また本発明では、前記反強磁性層が、Ｘ－Ｍｎ－Ｘ′合金で形成される場合、Ｘ′の組成比はａｔ％で、０．２～１０の範囲内であることが好ましく、より好ましくは、０．５～５の範囲内である。

【0026】さらに本発明では、前記反強磁性層が、Ｘ－Ｍｎ－Ｘ′合金で形成される場合、元素ＸとＭｎとの組成比の割合Ｘ：Ｍｎは、４：６～６：４の範囲内であることが好ましい。なお前記反強磁性層として用いられるＸ－Ｍｎ－Ｘ′合金は、スパッタ法により形成されることが好ましい。

【0027】本発明では、前記反強磁性層が、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成され、前記反強磁性層が強磁性層の上に形成されており、Ｘ－Ｍｎ合金のＸの組成比はａｔ％で、４７～５７の範囲内であることが好ましい。

【0028】また本発明では、前記反強磁性層が、Ｘ－Ｍｎ－Ｘ′合金（ただし、Ｘは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素であり、Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成され、前記反強磁性層が強磁性層の上に形成されており、Ｘ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、４７～５７の範囲内であることが好ましい。

【0029】さらに本発明では、Ｘ－Ｍｎ合金のＸの組成比、あるいはＸ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、５０～５６の範囲内であることがより好ましい。

【0030】本発明では、前記反強磁性層が、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成され、前記反強磁性層が強磁性層の下に形成されており、Ｘ－Ｍｎ合金のＸの組成比はａｔ％で、４４～５７の範囲内であることが好ましい。

【0031】また本発明では、前記反強磁性層が、Ｘ－Ｍｎ－Ｘ′合金（ただしＸ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成され、前記反強磁性層が強磁性層の下に形成されており、Ｘ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、４４～５７の範囲内であることが好ましい。

【0032】さらに本発明では、Ｘ－Ｍｎ合金のＸの組成比、あるいはＸ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、４６～５５の範囲内であることがより好ましい。

【0033】以上のようにして形成された交換結合膜

は、本発明では、様々な磁気抵抗効果素子に使用可能である。まず本発明におけるシングルスピンバルブ型薄膜素子は、反強磁性層と、この反強磁性層と接して形成され、前記反強磁性層との交換異方性磁界により磁化方向が固定される固定磁性層と、前記固定磁性層に非磁性導電層を介して形成されたフリー磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向へ揃えるバイアス層と、固定磁性層と非磁性導電層とフリー磁性層に検出電流を与える導電層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、前述した交換結合膜により形成されていることを特徴とするものである。

【0034】また本発明では、上記シングルスピンバルブ型薄膜素子のフリー磁性層の上側または下側に、トラック幅Twの間隔を空けて反強磁性層が形成され、前記反強磁性層とフリー磁性層とが、前述した交換結合膜により形成されているものであってもよい。

【0035】また本発明におけるデュアルスピンバルブ型薄膜素子は、フリー磁性層の上下に積層された非磁性導電層と、一方の前記非磁性導電層の上および他方の非磁性導電層の下に位置する固定磁性層と、一方の前記固定磁性層の上および他方の固定磁性層の下に位置して、交換異方性磁界によりそれぞれの固定磁性層の磁化方向を一定の方向に固定する反強磁性層と、前記フリー磁性層の磁化方向を前記固定磁性層の磁化方向と交叉する方向に揃えるバイアス層とを有し、前記反強磁性層とこの反強磁性層と接して形成された固定磁性層とが、前述した交換結合膜により形成されていることを特徴とするものである。

【0036】さらに本発明におけるAMR素子は、非磁性層を介して重ねられた磁気抵抗層と軟磁性層とを有し、前記磁気抵抗層の上側あるいは下側にトラック幅Twの間隔を空けて反強磁性層が形成され、前記反強磁性層と磁気抵抗層とが、前述した交換結合膜により形成されていることを特徴とするものである。また本発明における薄膜磁気ヘッドは、前述した磁気抵抗効果素子の上下にギャップ層を介してシールド層が形成されていることを特徴とするものである。

【0037】本発明では、反強磁性層として、少なくとも元素X（X＝Pt，Pd，Ir，Rh，Ru，Osのうちいずれか1種あるいは2種以上の元素）とMnとを含む反強磁性材料を使用した場合、強磁性層との界面構造を非整合状態として、適性に交換異方性磁界を得られるようにするものである。

【0038】強磁性層との界面構造を非整合状態とする理由は、熱処理を施したとき、反強磁性層の結晶構造を、不規則格子から規則格子に適性に変態させ、より大きい交換異方性磁界を発生させるためである。以下に、前記非整合状態と交換異方性磁界との関係について詳述する。

【0039】まず、非整合状態とは、反強磁性層と強磁性層との界面において、前記反強磁性層側の原子と、強磁性層側の原子とが1対1に対応しておらず、原子の位置関係が異なることをいうが、このように界面構造を非整合状態とするには、熱処理前における反強磁性層の格子定数を適性に制御しておく必要がある。

【0040】本発明では、前記反強磁性層は、例えばX－Mn合金（ただし、XはPt，Pd，Ir，Rh，Ru，Osのうちいずれか1種あるいは2種以上の元素）で形成される。

【0041】本発明では、前記X－Mn合金のXの組成比を適性に選択して、熱処理前におけるX－Mn合金の格子定数の値と、強磁性層（例えばNiFe合金）の格子定数の値との差が大きくなるようにしている。

【0042】成膜段階（熱処理前）におけるX－Mn合金の結晶構造と強磁性層の結晶構造とは共に、X，Mn原子の配列順序が不規則な面心立方格子（以下、不規則格子という）となっているが、本発明では前述したように、X－Mn合金の格子定数と強磁性層の格子定数との差を大きくしているので、成膜段階（熱処理前）でのX－Mn合金と強磁性層との界面構造は非整合状態になりやすくなっている。

【0043】このように本発明では、反強磁性層としてX－Mn合金（XはPt，Pd等）を使用した場合、元素Xの組成比を適正に選択することにより、反強磁性層と、強磁性層との界面状態を非整合状態にしているが、さらに本発明では、希ガス元素（NeやAr等）などの元素X′をX－Mn合金に含有させることで、反強磁性層の格子定数を大きくでき、前記反強磁性層と強磁性層との界面構造を非整合状態にすることが可能になっている。

【0044】また本発明では、X－Mn合金、あるいはX－Mn－X′合金と強磁性層との結晶配向が異なるようにしておくことが好ましい。結晶配向度は下地層の存否や、組成比、スパッタ成膜時の電力ガス圧等の諸条件、あるいは膜の積層順などにより変えることが可能である。

【0045】このように、X－Mn合金、あるいはX－Mn－X′合金と強磁性層との結晶配向が異なるようにしておくのは、例えば強磁性層の｛111｝面が、膜面に平行に優先配向し、同じ様にX－Mn合金、あるいはX－Mn－X′合金の｛111｝面が、膜面に平行に優先配向していると、界面構造は非整合状態には成りにくくなるからである。

【0046】そこで本発明では、例えば強磁性層の｛111｝面が、X－Mn合金、あるいはX－Mn－X′合金との界面に平行な方向に優先配向している場合、X－Mn合金、あるいはX－Mn－X′合金の｛111｝面の配向度は、前記強磁性層の配向度よりも小さいか、あるいは無配向となるように適性に制御することで、界面

構造を非整合状態に保つことが可能となる。

【0047】以上のように、界面構造が非整合状態となるように、X－Mn合金、あるいはX－Mn－X′合金と強磁性層とを積層した後、熱処理を施すことにより、X－Mn合金、あるいはX－Mn－X′合金と強磁性層との界面にて交換異方性磁界が発生するが、この交換異方性磁界の発生は、X－Mn合金、あるいはX－Mn－X′合金の結晶構造が、前記不規則相からX，Mn原子の配列順序が規則性をもって決められた面心正方格子に変態することによるものである。

【0048】なお、本発明では、前記面心正方格子は、単位格子の6面のうち、側面の4面の中心をX原子が占め、単位格子の隅、および上面および下面の中心にMn原子が占める、いわゆる$L1_0$型の面心正方格子（以下、規則格子という）であり、熱処理後におけるX－Mn合金、あるいはX－Mn－X′合金の少なくとも一部の結晶構造が、前記規則格子となっている必要がある。

【0049】以上のように、熱処理を施すことによりX－Mn合金、あるいはX－Mn－X′合金の結晶構造が、不規則格子から規則格子に変態し、交換結合磁界が発生するが、この変態の際に生じる格子歪みは、X－Mn合金、あるいはX－Mn－X′合金の方がNiMn合金に比べて大きくなっている。

【0050】本発明では、前述したように、X－Mn合金の組成比を適性化することにより、あるいはX－Mn合金に第3元素として元素X′を添加することにより、熱処理前におけるX－Mn合金、あるいはX－Mn－X′合金と強磁性層との界面構造を非整合状態にできる。

【0051】反強磁性層と強磁性層との界面構造を非整合状態にすると、熱処理を施すことにより、X－Mn合金、あるいはX－Mn－X′合金の結晶構造は不規則格子から規則格子に変態しやすくなり、従って前記界面にて大きな交換異方性磁界が発生する。なお、X－Mn合金（X＝Pt，Pd等）、あるいはX－Mn－X′合金（X′＝Ne，Ar等）は、FeMn合金やNiMn合金などに比べて耐食性に優れ、またFeMn合金等に比べて、ブロッキング温度も高く、さらに交換異方性磁界（Hex）が大きいなど反強磁性材料として優れた特性を有している。また、本発明ではX－Mn合金、あるいはX－Mn－X′合金を構成する元素XにPtを選択することが好ましい。

【0052】以上詳述した、X－Mn合金、あるいはX－Mn－X′合金で形成された反強磁性層と強磁性層とから成る交換結合膜は、磁気抵抗効果素子に適用することが可能である。

【0053】本発明では、例えば前記磁気抵抗効果素子としてシングルスピンバルブ型薄膜素子およびデュアルスピンバルブ型薄膜素子の反強磁性層と固定磁性層とを、前記交換結合膜により形成している。これにより、前記固定磁性層の磁化を一定方向に強固に固定することが可能となり、従来に比べて優れた再生特性を得ることが可能となっている。

【0054】また、エクスチェンジバイアス方式により、例えばシングルスピンバルブ型薄膜素子のフリー磁性層、あるいはAMR素子の磁気抵抗効果素子層の磁化方向を一定の方向に揃える場合、エクスチェンジバイアス層とフリー磁性層、あるいはエクスチェンジバイアス層と磁気抵抗層とを、前記交換結合膜により形成してもよい。これにより、前記フリー磁性層および磁気抵抗層の磁化を一定方向に適性に揃えることが可能となり、優れた再生特性を得ることが可能である。

【0055】

【発明の実施の形態】図1は、本発明の第1実施形態のシングルスピンバルブ型薄膜素子の構造をABS面側から見た断面図である。なお、図1ではX方向に延びる素子の中央部分のみを破断して示している。このシングルスピンバルブ型薄膜素子は、ハードディスク装置に設けられた浮上式スライダのトレーリング側端部などに設けられて、ハードディスクなどの記録磁界を検出するものである。なお、ハードディスクなどの磁気記録媒体の移動方向はZ方向であり、磁気記録媒体からの洩れ磁界の方向はY方向である。

【0056】図1の最も下に形成されているのはTa（タンタル）などの非磁性材料で形成された下地層6である。この下地層6の上にフリー磁性層1、非磁性導電層2、固定磁性層3、および反強磁性層4が積層されている。そして、前記反強磁性層4の上にTa（タンタル）などの保護層7が形成されている。

【0057】また図1に示すように、下地層6から保護層7までの6層の両側には、ハードバイアス層5，5が形成され、前記ハードバイアス層5，5の上には導電層8，8が積層されている。

【0058】本発明では前記フリー磁性層1および固定磁性層3が、NiFe合金、CoFe合金、Co合金、Co、CoNiFe合金などにより形成されている。なお図1に示すようにフリー磁性層1は一層で形成されているが、これが多層構造で形成されてもよい。つまり、前記フリー磁性層1が、例えばNiFe合金とCoFe合金とが積層された構造となっていてもよいし、NiFe合金とCoとが積層された構造でもよい。

【0059】前記フリー磁性層1と固定磁性層3との間に介在する非磁性導電層2は、Cuで形成されている。さらに、ハードバイアス層5，5は、例えばCo－Pt（コバルト－白金）合金やCo－Cr－Pt（コバルト－クロム－白金）合金などで形成されており、導電層8，8は、Cu（銅）やW（タングステン）、Cr（クロム）などで形成されている。

【0060】本発明では、固定磁性層3の上に形成されている反強磁性層4は、少なくとも元素X（ただしX

は、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）とＭｎとを含有する反強磁性材料によって形成されている。

【００６１】本発明では、図１に示す固定磁性層３と反強磁性層４との界面構造は、非整合状態となっており、また界面における前記反強磁性層４の少なくとも一部の結晶構造は、$L1_0$型の面心正方格子（以下、規則格子という）となっている。

【００６２】ここで、$L1_0$型の面心正方格子とは、単位格子の６面のうち、側面の４面の中心をＸ原子（Ｘ＝Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓ）が占め、単位格子の隅、および上面および下面の中心にＭｎ原子が占めるものをいう。

【００６３】また本発明では、固定磁性層３と反強磁性層４との結晶配向が異なっていることが、固定磁性層３と反強磁性層４との界面構造が、非整合状態になりやすい点で好ましい。

【００６４】図１に示すシングルバルブ型薄膜素子では、Ｔａの下地層６が敷いてあるので、前記下地層６の上に形成されるフリー磁性層１、非磁性導電層２、および固定磁性層３の｛１１１｝面は、膜面に対して平行な方向に優先配向している。

【００６５】これに対し、前記固定磁性層３の上に形成される反強磁性層４の｛１１１｝面は、前記固定磁性層３の｛１１１｝面の配向度に比べて小さいか、あるいは無配向となっている。つまり、図１に示す固定磁性層３と反強磁性層４との界面付近での結晶配向は異なったものとなっており、従って前記界面における構造が非整合状態になりやすくなっている。

【００６６】本発明では熱処理前の段階から、固定磁性層３と反強磁性層４との界面構造を非整合状態としているが、これは熱処理を施すことにより、前記反強磁性層４の結晶構造を、不規則格子（面心立方格子）から前述した規則格子に変態させ、適性な交換異方性磁界を得られるようにするためである。言い変えれば、界面構造が整合状態にあると、熱処理を施しても、前記反強磁性層４の結晶構造が、不規則格子から規則格子に変態しにくく、従って交換異方性磁界が得られないという問題が生じる。

【００６７】本発明では、前記反強磁性層４は、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成されている。特に本発明では、前記反強磁性層４がＰｔＭｎ合金により形成されていることが好ましい。Ｘ－Ｍｎ合金、特にＰｔＭｎ合金は、従来から反強磁性層として使用されているＦｅＭｎ合金、ＮｉＭｎ合金などに比べて耐熱性に優れており、またブロッキング温度も高く、さらに交換異方性磁界（Ｈｅｘ）が大きいなど反強磁性材料として優れた特性を有している。

【００６８】本発明では、前記反強磁性層４がＰｔＭｎ合金で形成されている場合、熱処理を施した後、つまり少なくとも一部の結晶構造が規則格子となった前記反強磁性層４の格子定数ａ，ｃの比ｃ／ａは、０．９３～０．９９の範囲内であることが好ましい。格子定数ａ，ｃの比ｃ／ａが０．９３以下になると、前記反強磁性層４の結晶構造のほぼ全てが規則格子となるが、このような状態になると、前記固定磁性層３と反強磁性層４との密着性が低下し、膜剥がれなどが発生し好ましくない。格子定数ａ，ｃの比ｃ／ａが０．９９以上になると、前記反強磁性層４の結晶構造のほぼ全てが不規則格子となってしまい、前記反強磁性層４と固定磁性層３との界面にて発生する交換異方性磁界が小さくなってしまい好ましくない。

【００６９】ところで前記反強磁性層４が、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成される場合、熱処理前の段階において、固定磁性層３と反強磁性層４との界面構造を非整合状態とするために、本発明では、前記Ｘ－Ｍｎ合金の組成比を下記の数値内に設定している。

【００７０】前記反強磁性層４が、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成され、しかも図１に示すように前記反強磁性層４が固定磁性層３の上に形成される場合、Ｘ－Ｍｎ合金の元素Ｘの組成比はａｔ％で、４７～５７の範囲内であることが好ましい。より好ましくはＸ－Ｍｎ合金の元素Ｘの組成比はａｔ％で、５０～５６の範囲内である。

【００７１】上述した組成比内で反強磁性層４を形成すると、熱処理前、つまり結晶構造が不規則格子となっている段階での前記反強磁性層４の格子定数と、固定磁性層３の格子定数との差を大きくすることができ、従って熱処理前にて、前記固定磁性層３と反強磁性層４との界面構造を非整合状態に保つことができる。

【００７２】この状態で熱処理を施すと、前記反強磁性層４の結晶構造の変化により、交換異方性磁界が発生し、前述したようにＸ－Ｍｎ合金の元素Ｘの組成比の組成比がａｔ％で、４７～５７の範囲内であると、４００（Ｏｅ：エルステッド）以上の交換異方性磁界を得ることが可能である。またＸ－Ｍｎ合金の元素Ｘの組成比はａｔ％で、５０～５６の範囲内であると、６００（Ｏｅ）以上の交換異方性磁界を得ることが可能である。

【００７３】このように本発明では、反強磁性層４としてＸ－Ｍｎ合金を使用した場合、元素Ｘの組成比を上述した範囲内で形成することにより、熱処理前における前記反強磁性層４と固定磁性層３との界面構造を非整合状態に保つことが可能である。また本発明では、Ｘ－Ｍｎ合金に、第３元素として元素Ｘ′を添加することにより、反強磁性層４の格子定数を大きくでき、熱処理前における反強磁性層４と固定磁性層３との界面構造を非整

合状態にすることが可能である。

【００７４】Ｘ－Ｍｎ合金に元素Ｘ′を加えたＸ－Ｍｎ－Ｘ′合金は、元素ＸとＭｎとで構成される空間格子の隙間に元素Ｘ′が侵入した侵入型固溶体であり、あるいは、元素ＸとＭｎとで構成される結晶格子の格子点の一部が、元素Ｘ′に置換された置換型固溶体である。ここで固溶体とは、広い組成範囲にわたって、均一に成分が混ざり合った固体のことを指している。なお本発明では元素ＸはＰｔであることが好ましい。

【００７５】ところで本発明では前記Ｘ－Ｍｎ－Ｘ′合金をスパッタ法により成膜している。スパッタによって、前記Ｘ－Ｍｎ－Ｘ′合金は非平衡状態で成膜され、成膜されたＸ－Ｍｎ－Ｘ′合金は、膜中の元素Ｘ′が、元素ＸとＭｎとで構成される空間格子の隙間に侵入し、あるいは、元素ＸとＭｎとで構成される結晶格子の格子点の一部が、元素Ｘ′に置換される。このように、前記元素Ｘ′が、Ｘ－Ｍｎ合金の格子に侵入型であるいは置換型で固溶することにより、格子は押し広げられ、反強磁性層４の格子定数は、元素Ｘ′を添加しない場合に比べ大きくなる。

【００７６】また本発明では、元素Ｘ′として様々な元素を使用することが可能であるが、反応性の高いハロゲンやＯ（酸素）等を使用すると、これらがＭｎとのみ選択的に化学結合してしまい、面心立方晶の結晶構造を保てなくなると考えられ好ましくない。本発明における具体的な元素Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ，及び希土類元素（Ｓｃ，Ｙとランタノイド（Ｌａ，Ｃｅ，Ｐｒ，Ｎｄ，Ｐｍ，Ｓｍ，Ｅｕ，Ｇｄ，Ｔｂ，Ｄｙ，Ｈｏ，Ｅｒ，Ｔｍ，Ｙｂ，Ｌｕ））のうち１種または２種以上の元素である。

【００７７】上記に示した様々な元素Ｘ′のいずれを使用しても、スパッタによって、反強磁性層４の格子定数を大きくできるが、特に置換型で固溶する元素Ｘ′を使用する場合は、前記元素Ｘ′の組成比が大きくなりすぎると、反強磁性としての特性が低下し、固定磁性層３との界面で発生する交換結合磁界が小さくなってしまう。

【００７８】特に本発明では、侵入型で固溶し、不活性ガスの希ガス元素（Ｎｅ，Ａｒ，Ｋｒ，Ｘｅのうち１種または２種以上）を元素Ｘ′として使用することが好ましいとしている。希ガス元素は不活性ガスなので、希ガス元素が、膜中に含有されても、反強磁性特性に大きく影響を与えることがなく、さらに、Ａｒなどは、スパッタガスとして従来からスパッタ装置内に導入されるガスであり、ガス圧やスパッタ粒子のエネルギーを適正に調節するのみで、容易に、膜中にＡｒを侵入させることができる。

【００７９】なお、元素Ｘ′にガス系の元素を使用した場合には、膜中に多量の元素Ｘ′を含有することは困難であるが、希ガスの場合においては、膜中に微量侵入させるだけで、熱処理によって発生する交換結合磁界を、飛躍的に大きくできることが実験により確認されている。

【００８０】なお本発明では、元素Ｘ′の組成比の範囲を設定しており、好ましい前記元素Ｘ′の組成範囲は、ａｔ％で０．２から１０であり、より好ましくは、ａｔ％で、０．５から５である。またこのとき、元素ＸとＭｎとの組成比の割合Ｘ：Ｍｎは、４：６～６：４の範囲内であることが好ましい。元素Ｘ′の組成比と、元素ＸとＭｎとの組成比の割合Ｘ：Ｍｎを、上記範囲内で調整すれば、成膜段階（熱処理前）における反強磁性層４の格子定数を大きくでき、しかも熱処理を施すことにより反強磁性層４と固定磁性層３との界面で発生する交換結合磁界を、元素Ｘ′を含有しない場合に比べ、大きくすることが可能である。

【００８１】さらに本発明では、Ｘ－Ｍｎ－Ｘ′合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素であり、Ｘ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成された反強磁性層４が、図１に示すように、固定磁性層３の上に形成される場合、前記Ｘ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、４７～５７の範囲内であることが好ましく、より好ましくは、Ｘ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、５０～５６の範囲内である。

【００８２】熱処理を施すことによって反強磁性層４と固定磁性層３との界面で発生する交換結合磁界により、前記固定磁性層３の磁化は、図１に示すＹ方向に単磁区化され固定される。なお、反強磁性層４として使用されるＸ－Ｍｎ－Ｘ′合金の元素Ｘ′が例えばガス系の元素である場合には、熱処理を施すことにより、前記元素Ｘ′が膜中から抜け出して、成膜された段階での元素Ｘ′の組成比よりも、熱処理後の元素Ｘ′の組成比は小さくなり、あるいは完全に前記Ｘ′が膜中から抜け出してしまって、組成がＸ－Ｍｎになってしまうことがあるが、成膜段階（熱処理前）における固定磁性層３と反強磁性層４との界面構造が非整合状態となっていれば、熱処理を施すことにより、前記反強磁性層４の結晶構造は、不規則格子（面心立方格子）から規則格子に適性に変態し、大きい交換異方性磁界を得ることが可能である。またフリー磁性層１は、その両側に形成されているハードバイアス層５，５により、図示Ｘ方向に揃えられる。

【００８３】図１に示すシングルスピンバルブ型薄膜素子では、導電層８からフリー磁性層１、非磁性導電層２

および固定磁性層３に定常電流（センス電流）が与えられ、しかも記録媒体からＹ方向へ磁界が与えられると、フリー磁性層１の磁化方向がＸ方向からＹ方向へ向けて変化する。このとき、伝導電子が、非磁性導電層２と固定磁性層３との界面、または非磁性導電層２とフリー磁性層１との界面で散乱を起こし、電気抵抗が変化する。よって電圧が変化し、検出出力を得ることができる。

【００８４】図２は、本発明の第２実施形態のシングルスピンバルブ型薄膜素子の構造を示す断面図である。図２に示すように、下から下地層６、反強磁性層４、固定磁性層３、非磁性導電層２、およびフリー磁性層１が連続して積層されている。なお、図２に示す反強磁性層４は、図１に示す反強磁性層４と同じ様に、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）、好ましくはＰｔＭｎ合金、またはＸ―Ｍｎ―Ｘ′合金（ただしＸ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成されている。なお、固定磁性層３、非磁性導電層２、およびフリー磁性層１は、図１で説明した材質で形成されている。

【００８５】この実施例においても、固定磁性層３と反強磁性層４との界面構造は、非整合状態となっており、また界面における前記反強磁性層４の少なくとも一部の結晶構造は、$L1_0$型の面心正方格子（以下、規則格子という）となっている。

【００８６】またＴａの下地層６の上に形成された前記反強磁性層４の｛１１１｝面は、界面に平行な方向に優先配向するが、図２に示すように、前記反強磁性層４の上に固定磁性層３が形成されると、前記固定磁性層３の｛１１１｝面の界面方向に対する配向度は、前記反強磁性層４の配向度よりも小さいか、あるいは無配向になり易い傾向がある。このように、図２では界面における前記反強磁性層４と固定磁性層３との結晶配向は異なっており、従ってより界面構造を非整合状態とすることが可能となっている。

【００８７】ところで、反強磁性層４がＸ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成され、図２に示すように、反強磁性層４が固定磁性層３の下に形成される場合、反強磁性層４を構成するＸ－Ｍｎ合金の元素Ｘの組成比はａｔ％で、４４～５７の範囲内であることが好ましい。この範囲内であれば、４００（Ｏｅ）以上の交換異方性磁界を得ることが可能である。より好ましくはＸ－Ｍｎ合金の元素Ｘの組成比はａｔ％で、４６～５５の範囲内である。この範囲内であれば、６００（Ｏｅ）以上の交換異方性磁界を得ることが可能である。

【００８８】このように上述した組成範囲内であると交換異方性磁界を大きくすることができるのは、熱処理前における反強磁性層４の格子定数（不規則格子）と、固定磁性層３の格子定数との差を大きくすることができ、熱処理前での界面構造を非整合状態とすることができるからである。従って熱処理を施すことにより、界面における前記反強磁性層４の少なくとも一部の結晶構造を、不規則格子から交換異方性磁界を発揮するために必要な規則格子に変態させることが可能となる。

【００８９】また前記反強磁性層４が、Ｘ－Ｍｎ－Ｘ′合金（ただしＸ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成される場合、前記Ｘ－Ｍｎ－Ｘ′合金は、スパッタ法によって形成され、元素ＸとＭｎとで構成される空間格子の隙間に元素Ｘ′が侵入した侵入型固溶体となり、あるいは、元素ＸとＭｎとで構成される結晶格子の格子点の一部が、元素Ｘ′に置換された置換型固溶体となっている。

【００９０】元素Ｘ′を膜中に含有する反強磁性層４の格子定数は、前記元素Ｘ′を含有しない反強磁性層４の格子定数に比べて大きくなり、成膜段階（熱処理前）における反強磁性層４と固定磁性層３との界面構造を非整合状態に保つことができる。

【００９１】なお本発明では、膜中に占める元素Ｘ′の組成比を、ａｔ％で、０．２～10の範囲内とし、より好ましい組成範囲をａｔ％で、０．５～５の範囲内としている。また元素Ｘ′を前記組成範囲内で形成し、さらに、元素ＸとＭｎとの組成比の割合Ｘ：Ｍｎを、４：６～６：４の範囲内とすれば、より大きい交換結合磁界を得ることが可能である。

【００９２】また本発明では、図２に示すように、Ｘ－Ｍｎ－Ｘ′合金で形成された反強磁性層４が固定磁性層３の下側に形成される場合、Ｘ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比は、ａｔ％で、４４～５７の範囲内であることが好ましい。より好ましくはＸ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、４６～５５の範囲内である。

【００９３】なお、図２に示す固定磁性層３の磁化は、反強磁性層４との界面にて発生する交換異方性磁界により、図示Ｙ方向に単磁区化され固定されている。

【００９４】図２に示すように、フリー磁性層１の上には、トラック幅Ｔｗの間隔を空けてエクスチェンジバイアス層９（反強磁性層）が形成されている。なおこのエクスチェンジバイアス層９は、Ｘ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）、好ましくはＰｔ

Mn合金、またはX－Mn－X′合金（ただしX′は、Ne，Ar，Kr，Xe，Be，B，C，N，Mg，Al，Si，P，Ti，V，Cr，Fe，Co，Ni，Cu，Zn，Ga，Ge，Zr，Nb，Mo，Ag，Cd，Ir，Sn，Hf，Ta，W，Re，Au，Pb，及び希土類元素のうち１種または２種以上の元素である）で形成されている。

【００９５】X－Mn合金の元素Xの組成比はａｔ％で、４７～５７の範囲内となっている。より好ましくはX－Mn合金の元素Xの組成比はａｔ％で、５０～５６の範囲内である。なおこの組成範囲は、図１で説明した反強磁性層４の組成範囲と同じである。またX－Mn－X′合金の場合、元素X′の組成比はａｔ％で、０．２～１０の範囲内であり、より好ましい組成範囲はａｔ％で、０．５～５の範囲内である。また元素XとMnとの組成比の割合X：Mnは、４：６～６：４の範囲内であることが好ましい。さらに、X－Mn－X′合金のX＋X′の組成比はａｔ％で、４７～５７の範囲内となっていることが好ましく、より好ましくはX－Mn－X′合金のX＋X′の組成比はａｔ％で、５０～５６の範囲内である。

【００９６】上述した組成範囲内であると、フリー磁性層１とエクスチェンジバイアス層９との界面構造は非整合状態となり、少なくとも界面にて４００（Oe）以上の交換異方性磁界を得ることができるが、図２に示すように、前記エクスチェンジバイアス層９，９は、トラック幅Tw部分には形成されていないので、フリー磁性層１の両端部分が、強く交換異方性磁界の影響を受け図示X方向に単磁区化され、フリー磁性層１のトラック幅Tw領域の磁化は、外部磁界に対して反応する程度に図示X方向に適性に揃えられている。

【００９７】このようにして形成されたシングルスピンバルブ型薄膜素子では、図示Y方向の外部磁界により、フリー磁性層１のトラック幅Tw領域の磁化が図示X方向から図示Y方向に変化する。このフリー磁性層１内での磁化の方向の変動と、固定磁性層３の固定磁化方向（図示Y方向）との関係で電気抵抗が変化し、この電気抵抗値の変化に基づく電圧変化により、記録媒体からの洩れ磁界が検出される。

【００９８】図３は、本発明の第３実施形態のデュアルスピンバルブ型薄膜素子の構造を示す断面図である。図に示す示すように、下から下地層６、反強磁性層４、固定磁性層３、非磁性導電層２、およびフリー磁性層１が連続して積層されている。さらに前記フリー磁性層１の上には、非磁性導電層２、固定磁性層３、反強磁性層４、および保護層７が連続して積層されている。また、下地層６から保護層７までの多層膜の両側にはハードバイアス層５，５、導電層８，８が積層されている。なお、各層は図１および図２で説明した材質と同じ材質で形成されている。

【００９９】図３に示すように、フリー磁性層１よりも下側に形成されている反強磁性層４は、固定磁性層３の下に形成されているので、図２に示す反強磁性層４と同じ様に、前記反強磁性層４を構成するX－Mn合金の元素Xの組成比はａｔ％で、４４～５７の範囲内であることが好ましく、より好ましくはX－Mn合金の元素Xの組成比はａｔ％で、４６～５５の範囲内である。

【０１００】また、フリー磁性層１よりも上側に形成されている反強磁性層４は、固定磁性層３の上に形成されているので、図１に示す反強磁性層４と同じ様に、前記反強磁性層４を構成するX－Mn合金の元素Xの組成比はａｔ％で、４７～５７の範囲内であることが好ましく、より好ましくはX－Mn合金の元素Xの組成比はａｔ％で、５０～５６の範囲内である。

【０１０１】この組成範囲内であれば、熱処理前における固定磁性層３の格子定数と反強磁性層４の格子定数との差を大きくすることができるので、熱処理前における界面構造を非整合状態にすることができ、従って熱処理を施すことにより、界面での前記反強磁性層４の一部の結晶構造を不規則格子から交換異方性磁界を発揮するのに必要な規則格子に変態させることが可能である。なお前記反強磁性層４がPtMn合金で形成される場合、熱処理後における前記反強磁性層４の格子定数ａ，ｃの比ｃ／ａは、０．９３～０．９９の範囲内であることが好ましい。また、反強磁性層４と固定磁性層３との結晶配向も異なっているので、より界面構造を非整合状態にすることが可能となっている。

【０１０２】上述した組成範囲内であれば、少なくとも４００（Oe）以上の交換異方性磁界を得ることが可能であるが、反強磁性層４を固定磁性層３の下に形成する方が、固定磁性層３の上に形成するよりも、X－Mn合金の元素Xの組成比の範囲を若干広くすることが可能である。

【０１０３】また反強磁性層４がX－Mn－X′合金で形成される場合は、元素X′の組成比は、ａｔ％で、０．２～１０の範囲内であり、より好ましい組成範囲はａｔ％で、０．５～５の範囲内である。また元素XとMnとの組成比の割合X：Mnは、４：６～６：４の範囲内であることが好ましい。

【０１０４】さらにフリー磁性層１よりも下側に形成されている反強磁性層４の場合、前記反強磁性層４を構成するX－Mn－X′合金のX＋X′の組成比はａｔ％で、４４～５７の範囲内であることが好ましく、より好ましくはX－Mn－X′合金のX＋X′の組成比はａｔ％で、４６～５５の範囲内である。

【０１０５】また、フリー磁性層１よりも上側に形成されている反強磁性層４の場合、前記反強磁性層４を構成するX－Mn－X′合金のX＋X′の組成比はａｔ％で、４７～５７の範囲内であることが好ましく、より好ましくはX－Mn－X′合金のX＋X′の組成比はａｔ

％で、５０～５６の範囲内である。

【０１０６】上記組成範囲内であれば、熱処理前における固定磁性層３の格子定数と反強磁性層４の格子定数との差を大きくすることができ、熱処理前における界面構造を非整合状態にすることができ、従って熱処理を施すことにより、界面での前記反強磁性層４の一部の結晶構造を不規則格子から交換異方性磁界を発揮するのに必要な規則格子に変態させることが可能である。

【０１０７】なおこのデュアルスピンバルブ型薄膜素子も図１に示すシングルスピンバルブ型薄膜素子と同じように、固定磁性層３は、交換異方性磁界により、図示Ｙ方向に単磁区化され固定されており、フリー磁性層１の磁化は、ハードバイアス層５，５の影響を受けて図示Ｘ方向に揃えられている。

【０１０８】導電層８からフリー磁性層１、非磁性導電層２および固定磁性層３に定常電流が与えられ、しかも記録媒体からＹ方向へ磁界が与えられると、フリー磁性層１の磁化は図示Ｘ方向からＹ方向に変動し、このとき非磁性導電層２とフリー磁性層１との界面、および非磁性導電層２と固定磁性層３との界面でスピンに依存した伝導電子の散乱が起こることにより、電気抵抗が変化し、記録媒体からの漏れ磁界が検出される。

【０１０９】なお、図１および図２に示すシングルスピンバルブ型薄膜素子では、スピンに依存した電子の散乱を起こす場所が、非磁性導電層２とフリー磁性層１との界面、および非磁性導電層２と固定磁性層３との界面の２箇所であるのに対し、図３に示すデュアルスピンバルブ型薄膜素子では、伝導電子の散乱が起こる場所が、非磁性導電層２とフリー磁性層１との２箇所の界面と、非磁性導電層２と固定磁性層３との２箇所の界面の計４箇所であるため、デュアルスピンバルブ型薄膜素子の方がシングルスピンバルブ型薄膜素子に比べて大きい抵抗変化率を得ることが可能である。

【０１１０】図４は、本発明の第４実施形態のＡＭＲ型薄膜素子の構造を示す断面図である。図に示すように、下から軟磁性層（ＳＡＬ層）１０、非磁性層（ＳＨＵＮＴ層）１１、および磁気抵抗層（ＭＲ層）１２が連続して積層されている。例えば前記軟磁性層１０は、Ｆｅ－Ｎｉ－Ｎｂ合金、非磁性層１１は、Ｔａ膜、磁気抵抗層１２は、ＮｉＦｅ合金により形成されている。

【０１１１】前記磁気抵抗層１２の上には、トラック幅Ｔｗを開けたＸ方向両側の部分にエクスチェンジバイアス層（反強磁性層）９，９が形成され、さらに、前記エクスチェンジバイアス層９，９の上には、Ｃｒ膜などで形成された導電層１３，１３が形成されている。

【０１１２】図４に示すエクスチェンジバイアス層９，９は、図２に示すエクスチェンジバイアス層９，９と同様に、Ｘ－Ｍｎ合金、好ましくはＰｔＭｎ合金で形成されており、Ｘ－Ｍｎ合金の元素Ｘの組成比はａｔ％で、４７～５７の範囲内となっている。より好ましくはＸ－Ｍｎ合金の元素Ｘの組成比はａｔ％で、５０～５６の範囲内である。

【０１１３】また前記エクスチェンジバイアス層９，９は、Ｘ－Ｍｎ－Ｘ′合金（ただしＸ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）で形成されており、元素Ｘ′の組成比は、ａｔ％で、０．２～１０の範囲内であり、より好ましい組成範囲はａｔ％で、０．５～５の範囲内である。また元素ＸとＭｎとの組成比の割合Ｘ：Ｍｎは、４：６～６：４の範囲内であることが好ましい。また図４に示すエクスチェンジバイアス層９，９は、図２に示すエクスチェンジバイアス層９，９と同様に、Ｘ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、４７～５７の範囲内となっている。より好ましくはＸ－Ｍｎ－Ｘ′合金のＸ＋Ｘ′の組成比はａｔ％で、５０～５６の範囲内である。

【０１１４】以上Ｘ－Ｍｎ合金あるいはＸ－Ｍｎ－Ｘ′合金の組成比を上述した範囲内で形成すれば、前記エクスチェンジバイアス層９，９と磁気抵抗層１２との界面構造は非整合状態となり、熱処理を施すことにより、ＮｉＦｅ合金の磁気抵抗層１２の膜厚が２００～３００オングストロームの場合は、前記界面にて約４０～１１０（Ｏｅ）の交換異方性磁界が得られ、とりわけ、ＮｉＦｅ合金の磁気抵抗層の膜厚が、約２００オングストロームの場合には、約６０～１１０（Ｏｅ）の交換異方性磁界が得られ、図４に示す磁気抵抗層１２のＢ領域が、図示Ｘ方向に単磁区化される。そしてこれに誘発されて前記磁気抵抗層１２のＡ領域の磁化が図示Ｘ方向に揃えられる。また、検出電流が磁気抵抗層１２を流れる際に発生する電流磁界が、軟磁性層１０にＹ方向に印加され、軟磁性層１０がもたらす静磁結合エネルギーにより、磁気抵抗層１２のＡ領域に横バイアス磁界がＹ方向に与えられる。Ｘ方向に単磁区化された磁気抵抗層１２のＡ領域にこの横バイアス層が与えられることにより、磁気抵抗層１２のＡ領域の磁界変化に対する抵抗変化（磁気抵抗効果特性：Ｈ－Ｒ効果特性）が直線性を有する状態に設定される。記録媒体の移動方向はＺ方向であり、図示Ｙ方向に漏れ磁界が与えられると、磁気抵抗層１２のＡ領域の抵抗値が変化し、これが電圧変化として検出される。

【０１１５】以上詳述したように、本発明では、反強磁性層４（あるいはエクスチェンジバイアス層９）をＸ－Ｍｎ合金（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）、好ましくはＰｔＭｎ合金で形成する際に、前記反強磁性層４の組成比を適性に調節することにより、前記反強磁性層４と、この反強磁性層４と接して形成される

固定磁性層３（あるいはフリー磁性層１または磁気抵抗層１２）との界面構造を非整合状態とすることができ、従ってより大きな交換異方性磁界を得られ、従来に比べて再生特性を高めることが可能である。あるいは、前記反強磁性層４（あるいはエクスチェンジバイアス層９）を元素ＸとＭｎ以外に、第３元素として元素Ｘ′（ただしＸ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）を添加することにより、前記元素Ｘ′を添加しない場合に比べ、反強磁性層４の格子定数を大きくすることができるので、前記反強磁性層４と、この反強磁性層４と接して形成される固定磁性層３（あるいはフリー磁性層１または磁気抵抗層１２）との界面構造を非整合状態とすることができ、従ってより大きな交換異方性磁界を得ることができ、従来に比べて再生特性を高めることが可能である。また反強磁性層４と固定磁性層３との結晶配向を異なるようにしておくことが、より界面構造を非整合状態にしやすくできる点で好ましい。

【０１１６】また界面構造を非整合状態としておくことで交換異方性磁界を得ることができるのは、熱処理を施すことにより、前記反強磁性層４の結晶構造を不規則格子から規則格子に変態させることができるからであるが、すべての結晶構造が規則格子に変態すると密着性などに問題が生じるため、一部の結晶構造のみが規則格子に変態していることが好ましい。例えば前記反強磁性層４がＰｔＭｎ合金で形成される場合、熱処理後における前記反強磁性層４の格子定数ａ，ｃの比ｃ／ａは、０．９３～０．９９の範囲内であることが好ましい（ちなみにすべての結晶構造が規則格子に変体した場合、前記格子定数ａ，ｃの比ｃ／ａは０．９１８である）。

【０１１７】なお、本発明では、磁気抵抗効果素子層の構造を図１～図４に示す構造に限定するものではない。例えば図１に示すシングルスピンバルブ型薄膜素子の場合、ハードバイアス層５，５を形成しないで、フリー磁性層１の下側にトラック幅Ｔｗの間隔を空けてエクスチェンジバイアス層を形成してもよいし、図２に示すシングルスピンバルブ型薄膜素子の場合、エクスチェンジバイアス層９，９を形成しないで、下地層６から保護層７までの６層の両側、あるいは少なくともフリー磁性層１の両側にハードバイアス層を形成してもよい。

【０１１８】図５は、図１から図４に示す磁気抵抗効果素子層が形成された読み取りヘッドの構造を記録媒体との対向面側から見た断面図である。符号２０は、例えばＮｉＦｅ合金などで形成された下部シールド層であり、この下部シールド層２０の上に下部ギャップ層２１が形成されている。また下部ギャップ層２１の上には、図１から図４に示す磁気抵抗効果素子層２２が形成されており、さらに前記磁気抵抗効果素子層２２の上には、上部ギャップ層２３が形成され、前記上部ギャップ層２３の上には、ＮｉＦｅ合金などで形成された上部シールド層２４が形成されている。

【０１１９】前記下部ギャップ層２１及び上部ギャップ層２３は、例えばSiO_2やAl_2O_3（アルミナ）などの絶縁材料によって形成されている。図５に示すように、下部ギャップ層２１から上部ギャップ層２３までの長さがギャップ長Ｇｌであり、このギャップ長Ｇｌが小さいほど高記録密度化に対応できるものとなっている。

【０１２０】

【実施例】本発明では、まず下記に示す膜構成から成る多層膜を成膜し、反強磁性層を構成する一元素のＰｔ量と、前記反強磁性層の格子定数との関係について調べた。膜構成としては、下からＳｉ基板／アルミナ／下地層：Ｔａ（１００）／固定磁性層：ＮｉＦｅ（３００）／反強磁性層：ＰｔＭｎ（３００）／Ｔａ（１００）の順で積層した。なお上記括弧中の数値は膜厚を表わしており、単位はオングストロームである。実験は熱処理を施さない段階で、Ｘ線回折のθ／２θ法により、Ｐｔ量と反強磁性層の格子定数との関係を、回折パターンのピーク位置から求めた。

【０１２１】図６に示すように、Ｐｔ量が増加するにつれて、反強磁性層（ＰｔＭｎ）の格子定数が大きくなっていることがわかる。また固定磁性層を構成するＮｉＦｅ合金、ＣｏＦｅ合金、またはＣｏの格子定数は、図に示すように、約３．５～３．６の範囲である。

【０１２２】次に、反強磁性層を固定磁性層の下、あるいは上に形成した２つの多層膜を、ＤＣマグネトロンスパッタ法により成膜し、熱処理を施した後におけるＰｔ量（反強磁性層を構成する一元素）と交換異方性磁界との関係について調べた。その実験結果を図７に示す。

【０１２３】反強磁性層が、固定磁性層の下に形成されている膜構成としては、下からＳｉ基板／アルミナ／下地層：Ｔａ（５０）／反強磁性層：ＰｔＭｎ（３００）／固定磁性層：$Co_{90}Fe_{10}$（３０）／保護層：Ｔａ（１００）の順で積層し、前記反強磁性層が、固定磁性層の上に形成されている膜構成としては下から、Ｓｉ基板／アルミナ／Ｔａ（５０）／固定磁性層：$Co_{90}Fe_{10}$（３０）／反強磁性層（３００）／保護層：Ｔａ（１００）の順で積層した。なお、上記括弧中の数値は膜厚を表わしており、単位はオングストロームである。

【０１２４】また熱処理工程における条件としては、まず昇温に３時間をかけ、次に２４０度の温度状態を３時間保持し、さらに、降温に３時間をかけた。なお、熱処理真空度を5×10^{-6}Ｔｏｒｒ以下とした。

【０１２５】図７に示すように、反強磁性層（ＰｔＭｎ合金）が、固定磁性層の下側にある場合、および上側にある場合共に、Ｐｔ量が約５０ａｔ％まで大きくなるにしたがって、交換異方性磁界は高くなっていき、Ｐｔ量

が約５０ａｔ％以上になると、交換異方性磁界は徐々に小さくなっているのがわかる。

【０１２６】４００（Ｏｅ）以上の交換異方性磁界を得るには、反強磁性層（ＰｔＭｎ）を固定磁性層の下側に形成した場合、Ｐｔ量を４４～５７ａｔ％の範囲内で、反強磁性層（ＰｔＭｎ）を固定磁性層の上側に形成した場合、Ｐｔ量を４７～５７ａｔ％の範囲内で適性に調節すればよいことがわかる。

【０１２７】また６００（Ｏｅ）以上の交換異方性磁界を得るには、反強磁性層（ＰｔＭｎ）を固定磁性層の下側に形成した場合、Ｐｔ量を４６～５５ａｔ％の範囲内＊＊で、反強磁性層（ＰｔＭｎ）を固定磁性層の上側に形成した場合、Ｐｔ量を５０～５６ａｔ％の範囲内で適性に調節すればよいことがわかる。

【０１２８】以上の実験結果から、反強磁性層（ＰｔＭｎ）の組成比を適性に調節した実施例として４種類の多層膜を成膜し、比較例として１種類の多層膜を成膜し、各膜の配向性や、交換異方性磁界等について調べた。その実験結果を表１に示す。

【０１２９】

【表１】

表1

		膜構成	PtMn組成 (at%)	PtMn／Co－Fe界面での格子整合	PtMnの{111}配向	強磁性層／Cu／強磁性層部分の{111}配向	240℃熱処理後のPtMnの規則化度	交換結合磁界, Hex (Oe)	抵抗変化率 (%)
実施例	①	基板／アルミナ／Ta(30Å)／PtMn(300Å)／Co－Fe(30Å)／Cu(22Å)／Co－Fe(10Å)／Ni－Fe(70Å)／Ta(50Å)	$Pt_{49}Mn_{51}$	なし	中	弱	○	770	8.7
	②	基板／アルミナ／PtMn(300Å)／Co(30Å)／Cu(24Å)／Ni－Fe(80Å)Ta(50Å)	$Pt_{50}Mn_{50}$	なし	弱	弱	○	730	4.5
	③	基板／アルミナ／Ta(50Å)／Ni－Fe(70Å)／Co－Fe(10Å)／Cu(28Å)／Co－Fe(30Å)／PtMn(300Å)／Ta(50Å)	$Pt_{51}Mn_{49}$	なし	弱	強	○	620	5.7
	④	基板／アルミナ／Ta(30Å)／PtMn(200Å)／Co－Fe(30Å)／Cu(22Å)／Co－Fe(10Å)／Ni－Fe(60Å)／Co－Fe(10Å)／Cu(22Å)／Co－Fe(30Å)／PtMn(200Å)／Ta(50Å)	$Pt_{49}Mn_{51}$	なし	中	弱	○	610	9.3
比較例	⑤	③と同一	$Pt_{44}Mn_{56}$	有り	強	強	×	40	0.2

実施例①～③までの多層膜は、シングルスピンバルブ型薄膜素子であり、実施例④の多層膜はデュアルスピンバルブ型薄膜素子である。また比較例⑤の多層膜は、実施例③の多層膜と同じ膜構成で、反強磁性層（ＰｔＭｎ）の組成比のみが異なっている。

【０１３０】また実施例①の多層膜には、Ｃｕ（非磁性導電層）の上に、Ｃｏ－ＦｅとＮｉ－Ｆｅが積層されているが、この２層でフリー磁性層が構成されている。同じ様に実施例③の多層膜には、Ｃｕ（非磁性導電層）の下に、Ｎｉ－ＦｅとＣｏ－Ｆｅが積層されているが、こ

の２層でフリー磁性層が構成されている。また実施例④の多層膜には、２つのＣｕ（非磁性導電層）の間に、Ｃｏ－Ｆｅ、Ｎｉ－Ｆｅ、およびＣｏ－Ｆｅが積層されているが、この３層でフリー磁性層が構成されている。

【０１３１】表１に示すように、実施例①～④までの多層膜では、ＰｔＭｎ（反強磁性層）とＣｏＦｅ（固定磁性層）との界面での格子整合は「なし」となっているのに対し、比較例⑤の多層膜では、界面での格子整合は「有り」となっている。また「２４０℃熱処理後のＰｔＭｎの規則化度」の欄を見ると、実施例①～④の多層膜では「○」となっているのに対し、比較例⑤の多層膜では「×」となっている。

【０１３２】さらに、「交換異方性磁界」および「抵抗変化率」の欄を見ると、実施例①～④までの多層膜では、大きい交換異方性磁界と抵抗変化率を有しているのに対し、比較例⑤の多層膜の交換異方性磁界および抵抗変化率は、実施例①～④の多層膜に比べて非常に小さくなっていることがわかる。

【０１３３】以上の実験結果は、ＰｔＭｎ合金の組成比に関係している。表１に示すように、比較例⑤におけるＰｔＭｎのＰｔ量は４４ａｔ％であるのに対し、実施例①～④までのＰｔＭｎのＰｔ量は、４９～５１ａｔ％となっている。

【０１３４】このため、図６（熱処理前）を参照すると、比較例⑤のＰｔＭｎの格子定数は、実施例①～④までのＰｔＭｎの格子定数よりも小さくなっており、比較例⑤の方が実施例①～④に比べて、ＰｔＭｎ（反強磁性層）の格子定数と、Ｃｏ－Ｆｅ（固定磁性層）の格子定数との差が小さくなっていることがわかる。

【０１３５】つまり、熱処理前の段階において、比較例⑤の多層膜では、ＰｔＭｎとＣｏＦｅとの界面構造が整合状態になりやすく、一方、実施例①～④までの多層膜では、ＰｔＭｎとＣｏＦｅとの界面構造が非整合状態になりやすくなっている。

【０１３６】熱処理前では、実施例①～④および比較例⑤のＰｔＭｎの結晶構造は、不規則格子（面心立方格子）となっているが、界面構造が整合状態となっている比較例⑤では熱処理を施しても、ＰｔＭｎの結晶構造は不規則格子から規則格子に変態できず、規則化は一向に進まない状態となっている。

【０１３７】これに対し、界面構造が非整合状態となっている実施例①～④の多層膜では、熱処理を施すことにより、ＰｔＭｎの結晶構造が不規則格子から一部が規則格子（Ｌ1_0型の面心正方格子）に変態し、規則化が充分に進行したものとなっている。

【０１３８】図８は、熱処理後における実施例③のＰｔＭｎとＣｏＦｅとの界面構造を示す高分解能ＴＥＭ写真である。図８に示すように、ＰｔＭｎとＣｏＦｅとの界面では、ＰｔＭｎの原子の並び方向とＣｏＦｅの原子の並び方向とが一致しておらず、非整合状態となっていることがわかる。

【０１３９】一方、図９は、熱処理後における比較例⑤のＰｔＭｎとＣｏＦｅとの界面構造を示す高分解能ＴＥＭ写真である。図９に示すように、ＰｔＭｎとＣｏＦｅとの界面では、ＰｔＭｎの原子の並び方向とＣｏＦｅの原子の並び方向とが一致しており、整合状態となっていることがわかる。

【０１４０】また図１０は、実施例③の多層膜におけるＰｔＭｎの規則化度を、図１１は比較例⑤の多層膜におけるＰｔＭｎの規則化度を測定した熱処理後の実験結果である。実験は、ＰｔＭｎにおける２つの等価な｛１１１｝面のなす角度を測定し、そのなす角度から規則化度を求めた。なお横軸は、ＰｔＭｎとＣｏＦｅとの界面からＰｔＭｎ側への距離を示している。

【０１４１】図１０に示すように、｛１１１｝面のなす角度の測定値は、約６５°から約７２°の範囲内に散らばっており、ＰｔＭｎの結晶構造は、熱処理前の不規則格子の一部が変化して、規則格子となっていることがわかる。

【０１４２】これに対し、図１１では、｛１１１｝面のなす角度の測定値が、約７０～約７１の範囲内に収まっており、ＰｔＭｎの結晶構造は、熱処理を施しても、熱処理前の不規則格子の状態を保ったままとなっていることがわかる。

【０１４３】以上のように、実施例①～④の多層膜では、ＰｔＭｎのＰｔ量を４９～５１ａｔ％とすることで、界面構造を非整合状態とすることができ、従って規則化を適性に進行させることができるので、図７を見てもわかるように、ＰｔＭｎとＣｏＦｅとの界面で発生する交換異方性磁界は非常に大きい値を有している。

【０１４４】一方、比較例⑤の多層膜では、ＰｔＭｎのＰｔ量が４４ａｔ％と低いので、界面構造は整合状態となり、従って規則化が適性に進まず、図７を見てもわかるように、ＰｔＭｎとＣｏＦｅとの界面で発生する交換異方性磁界は非常に小さい値となってしまう。またＰｔＭｎとＣｏＦｅとの界面構造を非整合状態とするには、ＰｔＭｎの結晶配向と、ＣｏＦｅの結晶配向とを異なるようにしておくことが好ましい。

【０１４５】なお、表１に示す｛１１１｝面の配向度の「強」「中」「弱」は、膜面方向に対する優先配向度を表わしている。表１に示すように、比較例⑤のＰｔＭｎの｛１１１｝面の配向度、およびＣｏＦｅ（固定磁性層）の｛１１１｝面の配向度は共に「強」となっている。

【０１４６】これは、実施例③の膜構成を参照すると、Ｔａの上に形成されたＮｉＦｅ，ＣｏＦｅ（フリー磁性層）、Ｃｕ（非磁性導電層）およびＣｏＦｅ（固定磁性層）は、下地層としてのＴａの影響を強く受けて、｛１１１｝面の配向度は強くなり、図６を参照してわかるように熱処理前におけるＣｏＦｅ（固定磁性層）の格子定

数とＰｔＭｎ（反強磁性層）の格子定数との差が小さいために、ＰｔＭｎの｛１１１｝面は、ＣｏＦｅの｛１１１｝面の配向度の影響を強く受けて、膜面方向に優先配向してしまう。

【０１４７】これに対し、実施例③ではＴａの上に形成されたＮｉＦｅ，ＣｏＦｅ（フリー磁性層）、Ｃｕ（非磁性導電層）およびＣｏＦｅ（固定磁性層）は、下地層としてのＴａの影響を強く受けて、｛１１１｝面の配向度は強くなるものの、図６を参照してわかるように熱処理前におけるＣｏＦｅ（固定磁性層）の格子定数とＰｔＭｎ（反強磁性層）の格子定数との差は大きいために、ＰｔＭｎの｛１１１｝面は、ＣｏＦｅの結晶配向の影響をあまり受けず、膜面方向における配向度は弱くなっている。

【０１４８】またＰｔＭｎの上にＣｏＦｅ（固定磁性層）が積層されている実施例①②の場合では、ＣｏＦｅがＰｔＭｎの上に形成されると、ＣｏＦｅの｛１１１｝面の配向度は弱くなり、従ってＰｔＭｎとＣｏＦｅとの結晶配向は、自動的に異なる方向に向けられる。

【０１４９】次に本発明では、反強磁性層をＰｔ－Ｍｎ－Ｘ′（Ｘ′＝Ａｒ）合金で形成し、元素Ｘ′量と、Ｐｔ－Ｍｎ－Ｘ′合金の格子定数との関係について調べた。実験に使用した膜構成は下から、Ｓｉ基板／アルミナ／Ｔａ（５０）／$Co_{90}Fe_{10}$（３０）／Ｐｔ－Ｍｎ－Ｘ′（３００）／Ｔａ（１００）である。なお括弧内の数値は膜厚を表しており、単位はオングストロームである。

【０１５０】反強磁性層の成膜は、スパッタ装置内に、ＰｔとＭｎとの割合が６：４、５：５、及び４：６となる３種類のターゲットを用意し、各ターゲットを用いて、元素Ｘ′となるＡｒの導入ガス圧を変化させながら、ＤＣマグネトロンスパッタ及びイオンビームスパッタによって、Ｐｔ－Ｍｎ－Ｘ′（Ｘ′＝Ａｒ）合金膜を形成した。そして、Ｐｔ－Ｍｎ－Ｘ′（Ｘ′＝Ａｒ）合金膜中に占めるＸ′（Ｘ′＝Ａｒ）量と、Ｐｔ－Ｍｎ－Ｘ′（Ｘ′＝Ａｒ）の格子定数との関係について測定した。その実験結果を図１２に示す。

【０１５１】図１２に示すように、ＰｔとＭｎとの組成比の割合が、６：４、５：５、及び４：６のいずれかの場合においても、元素Ｘ′（Ｘ′＝Ａｒ）量が大きくなることにより、Ｐｔ－Ｍｎ－Ｘ′（Ｘ′＝Ａｒ）の格子定数は大きくなることがわかる。なお固定磁性層を構成するＮｉＦｅ合金、ＣｏＦｅ合金、またはＣｏ　の格子定数は、図１２に示すように、約３．５～３．６の範囲である。またこの実験では、元素Ｘ′（Ｘ′＝Ａｒ）量を４ａｔ％程度までとし、それ以上大きい含有量の場合について実験を試みていないが、これは、元素Ｘ′となるＡｒはガス元素であるために、ガス圧を上げても、膜中にＡｒを含有しにくいことによるものである。

【０１５２】次に、上述の実験に使用したＰｔ－Ｍｎ－Ｘ′（Ｘ′＝Ａｒ）合金膜に対し、以下に記載する熱処理工程を施した。熱処理工程における条件としては、まず昇温に３時間をかけ、次に２４０度の温度状態を３時間保持し、さらに、降温に３時間をかけた。なお、熱処理真空度を5×10^{-6}Ｔｏｒｒ以下とした。

【０１５３】図１３は、Ｐｔ－Ｍｎ－Ｘ′（Ｘ′＝Ａｒ）合金膜の元素Ｘ′（Ｘ′＝Ａｒ）量と、前記熱処理によって、反強磁性層と固定磁性層との界面に発生した交換結合磁界の大きさとの関係を示すグラフである。図１３に示すように、元素Ｘ′（Ｘ′＝Ａｒ）量が大きくなると、交換結合磁界は大きくなっていることがわかる。すなわち、元素Ｘ′（Ｘ′＝Ａｒ）をＰｔＭｎに添加すれば、元素Ｘ′（Ｘ′＝Ａｒ）を添加しない場合に比べて大きい交換結合磁界を得ることが可能である。

【０１５４】次に本発明では、別の元素Ｘ′を用いて、反強磁性層をＰｔ－Ｍｎ－Ｘ′（Ｘ′＝Ｍｏ）合金で形成し、元素Ｘ′（Ｘ′＝Ｍｏ）量と、Ｐｔ－Ｍｎ－Ｘ′（Ｘ′＝Ｍｏ）合金膜の格子定数との関係について調べた。実験に使用した膜構成は下から、Ｓｉ基板／アルミナ／Ｔａ（５０）／$Co_{90}Fe_{10}$（３０）／Ｐｔ－Ｍｎ－Ｘ′（３００）／Ｔａ（１００）である。なお括弧内の数値は膜厚を表しており、単位はオングストロームである。

【０１５５】反強磁性層の成膜には、ＰｔＭｎのターゲットに元素Ｘ′（Ｘ′＝Ｍｏ）のチップを貼り合わせた複合型ターゲットを用意し、ターゲットに占めるチップの面積比を変化させながら、膜中に占める元素Ｘ′（Ｘ′＝Ｍｏ）量を変化させて、前記元素Ｘ′（Ｘ′＝Ｍｏ）量とＰｔ－Ｍｎ－Ｘ′（Ｘ′＝Ｍｏ）合金の格子定数との関係について測定した。その実験結果を図１４に示す。

【０１５６】図１４に示すように、ＰｔとＭｎとの組成比の割合が６：４、１：１、４：６のいずれかの場合においても、膜中に占める元素Ｘ′（Ｘ′＝Ｍｏ）の濃度が大きくなるほど、Ｐｔ－Ｍｎ－Ｘ′（Ｘ′＝Ｍｏ）の格子定数は大きくなることがわかる。なお固定磁性層を構成するＮｉＦｅ合金、ＣｏＦｅ合金、またはＣｏの格子定数は、図１４に示すように、約３．５～３．６の範囲である。

【０１５７】次に、上記実験で使用したＰｔ－Ｍｎ－Ｘ′（Ｘ′＝Ｍｏ）合金膜に対し、以下に記載する熱処理工程を施した。熱処理工程における条件としては、まず昇温に３時間をかけ、次に２４０度の温度状態を３時間保持し、さらに、降温に３時間をかけた。なお、熱処理真空度を5×10^{-6}Ｔｏｒｒ以下とした。

【０１５８】図１５は、Ｐｔ－Ｍｎ－Ｘ′（Ｘ′＝Ｍｏ）合金膜の元素Ｘ′（Ｘ′＝Ｍｏ）の濃度と、前記熱処理によって、反強磁性層と固定磁性層との界面に発生した交換結合磁界の大きさとの関係を示すグラフである。図１５に示すように、ＰｔとＭｎとの組成比の割合

が、６：４、１：１、４：６のいずれの場合であっても、膜中の元素Ｘ′（Ｘ′＝Ｍｏ）量が約３ａｔ％以上になれば、交換結合磁界は徐々に低下していくことがわかる。特に、膜中の元素Ｘ′（Ｘ′＝Ｍｏ）量が約１０ａｔ％以上になると、ＰｔとＭｎとの組成比の割合が１：１の場合であっても、交換結合磁界は非常に小さくなってしまい好ましくない。

【０１５９】ところで、元素Ｘ′（Ｘ′＝Ｍｏ）の適性な含有量であるが、少なくとも、前記元素Ｘ′（Ｘ′＝Ｍｏ）を含有しない場合、すなわち、元素Ｘ′（Ｘ′＝Ｍｏ）量が０ａｔ％のときよりも、交換結合磁界が大きくなることが好ましい。Ｐｔ：Ｍｎの組成比の割合が、６：４の場合は、元素Ｘ′（Ｘ′＝Ｍｏ）量が、約１ａｔ％以下であれば、元素Ｘ′（Ｘ′＝Ｍｏ）量が０ａｔ％のときよりも、交換結合磁界が大きくなる。また、Ｐｔ：Ｍｎの組成比の割合が、１：１の場合は、元素Ｘ′（Ｘ′＝Ｍｏ）量が、約７ａｔ％以下であれば、元素Ｘ′（Ｘ′＝Ｍｏ）量が０ａｔ％のときよりも、交換結合磁界が大きくなる。さらに、Ｐｔ：Ｍｎの組成比の割合が、４：６の場合は、元素Ｘ′（Ｘ′＝Ｍｏ）量が、約１０ａｔ％以下であれば、元素Ｘ′（Ｘ′＝Ｍｏ）量が０ａｔ％のときよりも、交換結合磁界が大きくなる。

【０１６０】次に、元素Ｘ′（Ｘ′＝Ｍｏ）の適性な含有量の下限であるが、Ｐｔ：Ｍｎの組成比の割合が、６：４の場合、元素Ｘ′（Ｘ′＝Ｍｏ）量が、約０．５ａｔ％になると、交換結合磁界が最も大きくなるので、そこで本発明では、元素Ｘ′（Ｘ′＝Ｍｏ）量が、０．５ａｔ％よりも小さい０．２ａｔ％を下限として設定した。

【０１６１】以上の実験結果から本発明では、元素Ｘ′の組成比の好ましい範囲をａｔ％で０．２から１０とした。またより好ましい範囲をａｔ％で０．５から５とした。なお上記の元素Ｘ′の好ましい組成範囲は、Ｐｔ（＝元素Ｘ）とＭｎとを４：６から６：４の範囲内に設定した場合である。

【０１６２】

【発明の効果】以上詳述した本発明によれば、反強磁性層と強磁性層とから成る交換結合膜において、前記反強磁性層をＸ－Ｍｎ（ただしＸは、Ｐｔ，Ｐｄ，Ｉｒ，Ｒｈ，Ｒｕ，Ｏｓのうちいずれか１種または２種以上の元素である）で形成する場合、前記反強磁性層の組成比を適性に調節して、前記反強磁性層と強磁性層（例えばＮｉＦｅ合金）との界面構造を非整合状態としているので、より大きい交換異方性磁界を得ることが可能となっている。

【０１６３】あるいは本発明では、元素Ｘ′（ただしＸ′は、Ｎｅ，Ａｒ，Ｋｒ，Ｘｅ，Ｂｅ，Ｂ，Ｃ，Ｎ，Ｍｇ，Ａｌ，Ｓｉ，Ｐ，Ｔｉ，Ｖ，Ｃｒ，Ｆｅ，Ｃｏ，Ｎｉ，Ｃｕ，Ｚｎ，Ｇａ，Ｇｅ，Ｚｒ，Ｎｂ，Ｍｏ，Ａｇ，Ｃｄ，Ｉｒ，Ｓｎ，Ｈｆ，Ｔａ，Ｗ，Ｒｅ，Ａｕ，Ｐｂ、及び希土類元素のうち１種または２種以上の元素である）を、Ｘ－Ｍｎ合金膜中に、侵入型、あるいは置換型で固溶させることにより、前記反強磁性層と強磁性層（例えばＮｉＦｅ合金）との界面構造を非整合状態にでき、より大きい交換異方性磁界を得ることが可能となっている。

【０１６４】また、熱処理を施した段階において、前記反強磁性層の少なくとも一部の結晶構造が、$L1_0$型の面心正方格子（規則格子）となっており、しかも前記反強磁性層の格子定数ａ，ｃの比ｃ／ａが、０．９３～０．９９の範囲内であることが、より大きい交換異方性磁界を得ることができる点で好ましい。さらに、界面における前記反強磁性層と強磁性層との結晶配向が異なっていることが、界面構造を非整合状態にしやすい点で好ましい。

【０１６５】以上のように、界面構造が非整合状態となっている交換結合膜を磁気抵抗効果素子に適用することにより、前記磁気抵抗効果素子層の抵抗変化率を高めることができ、再生特性を向上させることが可能となっている。

【図面の簡単な説明】

【図１】本発明の第１実施形態のシングルスピンバルブ型薄膜素子の構造をＡＢＳ面側から見た断面図、

【図２】本発明の第２実施形態のシングルスピンバルブ型薄膜素子の構造をＡＢＳ面側から見た断面図、

【図３】本発明の第３実施形態のデュアルスピンバルブ型薄膜素子の構造をＡＢＳ面側から見た断面図、

【図４】本発明の第４実施形態のＡＭＲ型薄膜素子の構造をＡＢＳ面側から見た断面図、

【図５】本発明における薄膜磁気ヘッドを記録媒体との対向面側から見た断面図、

【図６】反強磁性層をＰｔＭｎで形成した場合における、熱処理前でのＰｔ量と前記反強磁性層の格子定数との関係を示すグラフ、

【図７】反強磁性層をＰｔＭｎで形成した場合におけるＰｔ量と交換異方性磁界との関係を示すグラフ、

【図８】表１に示す実施例③の多層膜の高分解能ＴＥＭ写真、

【図９】表１に示す比較例⑤の多層膜の高分解能ＴＥＭ写真、

【図１０】表１に示す実施例③の多層膜におけるＰｔＭｎ（反強磁性層）の規則化度を示すグラフ、

【図１１】表１に示す実施例⑤の多層膜におけるＰｔＭｎ（反強磁性層）の規則化度を示すグラフ、

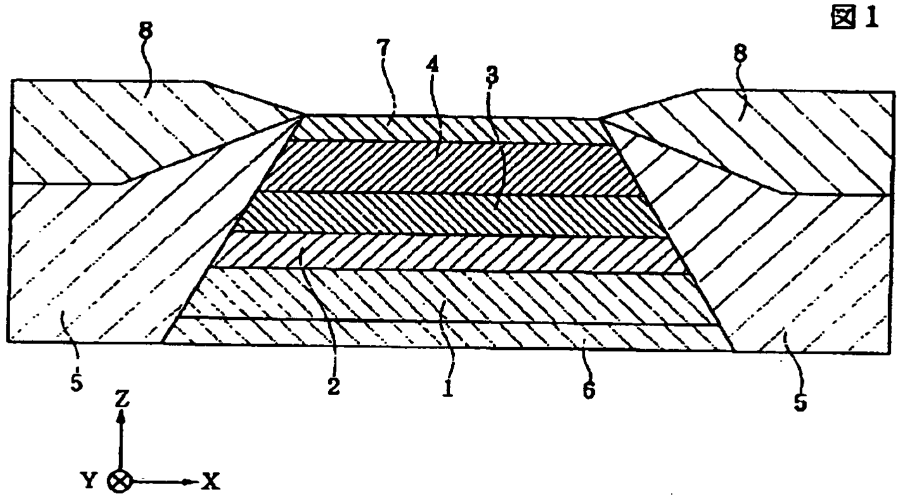
【図１２】反強磁性層をＰｔ－Ｍｎ－Ｘ′（Ｘ′＝Ａｒ）で形成した場合における元素Ｘ′（Ｘ′＝Ａｒ）量と前記反強磁性層の格子定数との関係を示すグラフ、

【図１３】反強磁性層をＰｔ－Ｍｎ－Ｘ′（Ｘ′＝Ａｒ）で形成した場合における元素Ｘ′（Ｘ′＝Ａｒ）量と交換結合磁界との関係を示すグラフ、

【図14】反強磁性層をＰｔ－Ｍｎ－Ｘ′（Ｘ′＝Ｍｏ）で形成した場合における元素Ｘ′（Ｘ′＝Ｍｏ）量と前記反強磁性層の格子定数との関係を示すグラフ、
【図15】反強磁性層をＰｔ－Ｍｎ－Ｘ′（Ｘ′＝Ｍｏ）で形成した場合における元素Ｘ′（Ｘ′＝Ｍｏ）量と交換結合磁界との関係を示すグラフ、
【符号の説明】
1　フリー磁性層
2　非磁性導電層
3　固定磁性層
4　反強磁性層
5　ハードバイアス層
6　下地層
7　保護層
8　導電層
9　エクスチェンジバイアス層
10　軟磁性層（ＳＡＬ層）
11　非磁性層（ＳＨＵＮＴ層）
12　磁気抵抗層（ＭＲ層）
20　下部シールド層
21　下部ギャップ層
22　磁気抵抗効果素子層
23　上部ギャップ層
24　上部シールド層

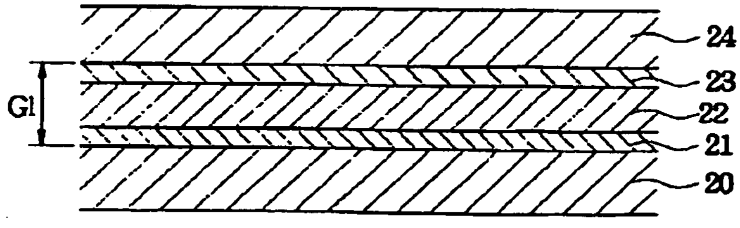
【図1】

図1



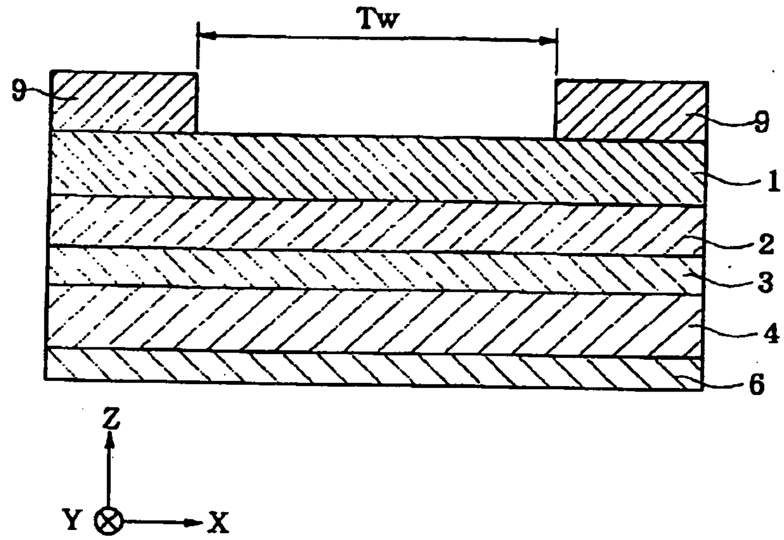
【図5】

図5



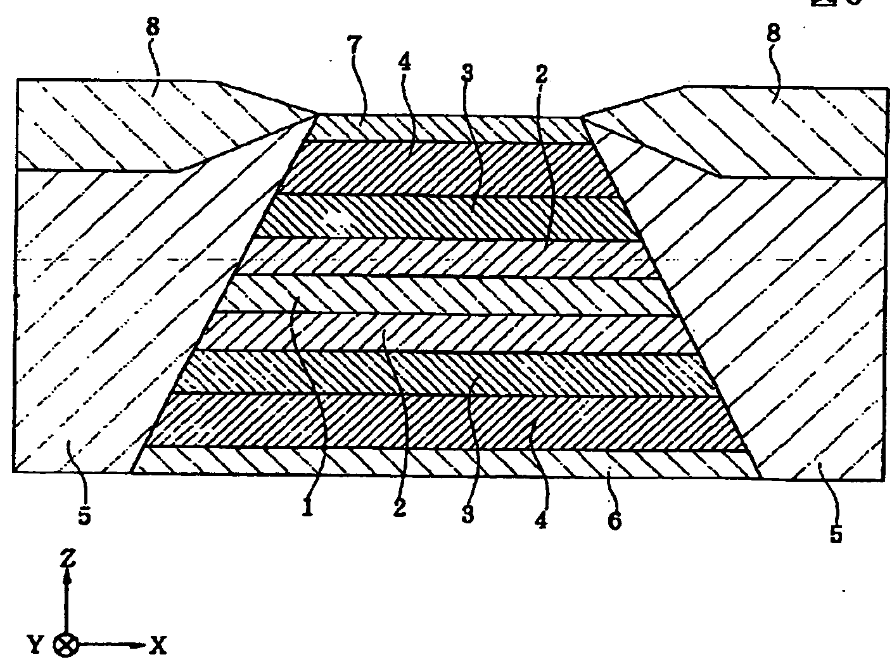
【図2】

図2



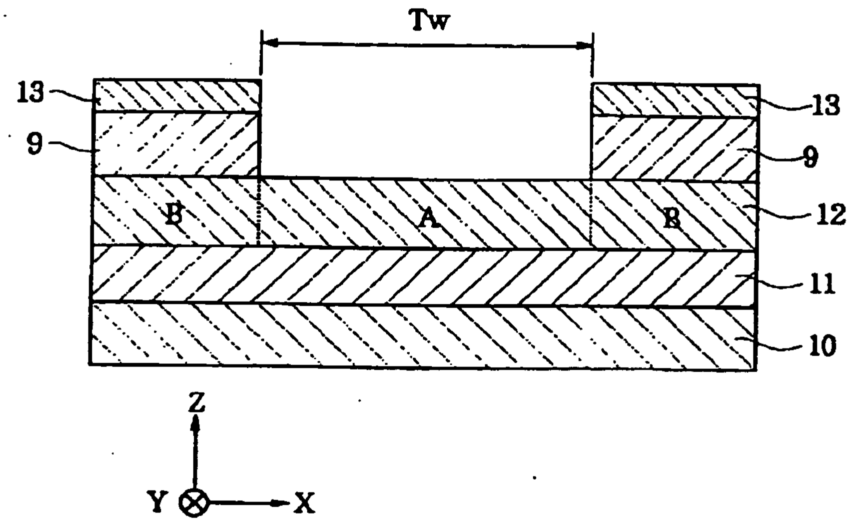
【図3】

図3



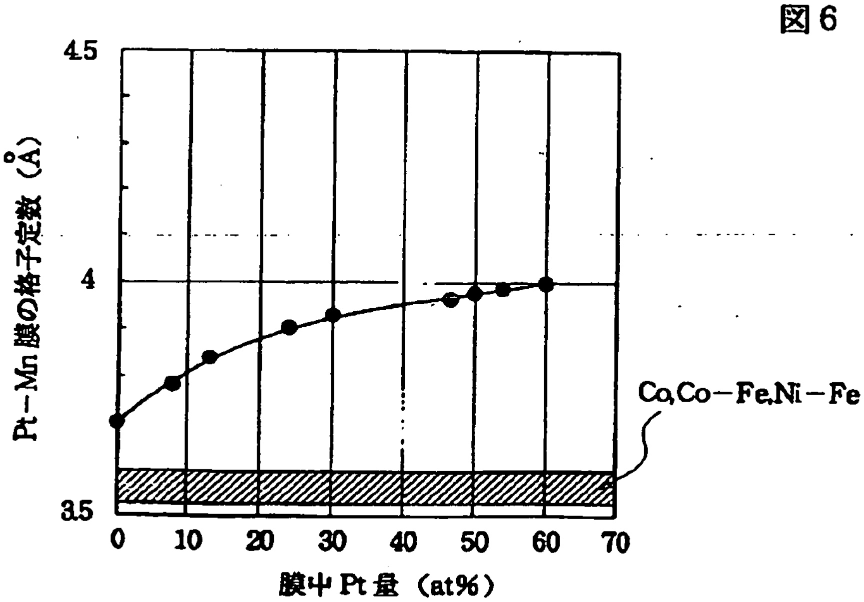
【図４】

図４


Tw
13
9
B
A
B
13
9
12
11
10
Z
Y
X

【図６】

図６


Pt－Mn膜の格子定数（Å）
4.5
4
3.5
0
10
20
30
40
50
60
70
膜中Pt量（at%）
Co,Co－Fe,Ni－Fe

【図7】

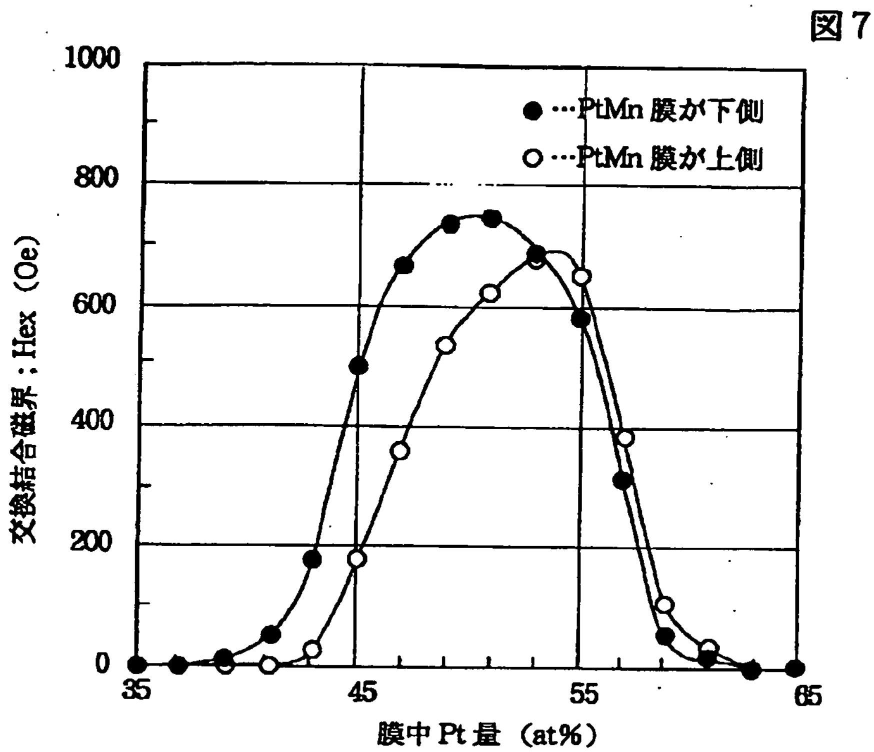


図7
1000
800
600
400
200
0
35
45
55
65
交換結合磁界：Hex（Oe）
膜中Pt量（at%）
●…PtMn膜が下側
○…PtMn膜が上側

【図10】

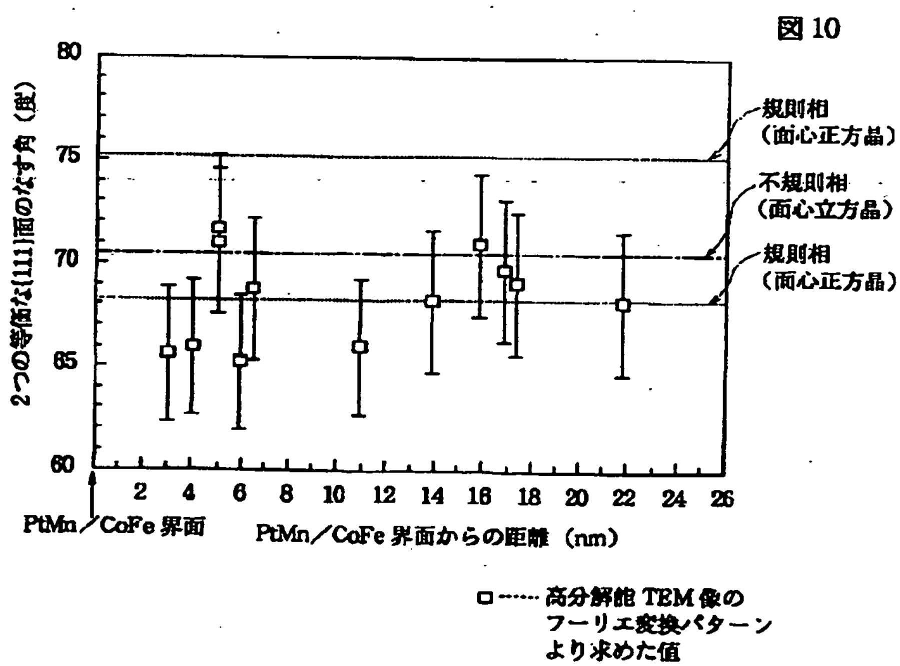


図10
80
75
70
65
60
2
4
6
8
10
12
14
16
18
20
22
24
26
2つの等価な{111}面のなす角（度）
PtMn／CoFe界面
PtMn／CoFe界面からの距離（nm）
規則相
（面心正方晶）
不規則相
（面心立方晶）
規則相
（面心正方晶）
□……高分解能TEM像の
フーリエ変換パターン
より求めた値

【図8】

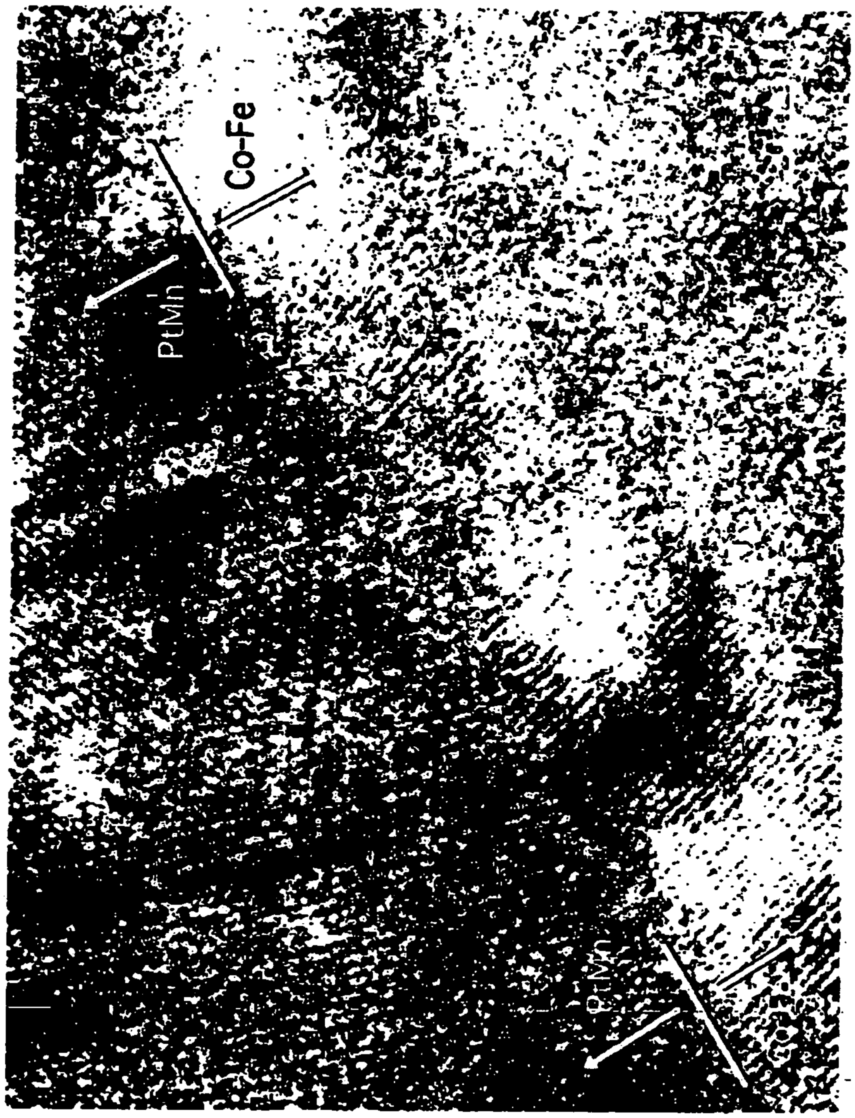


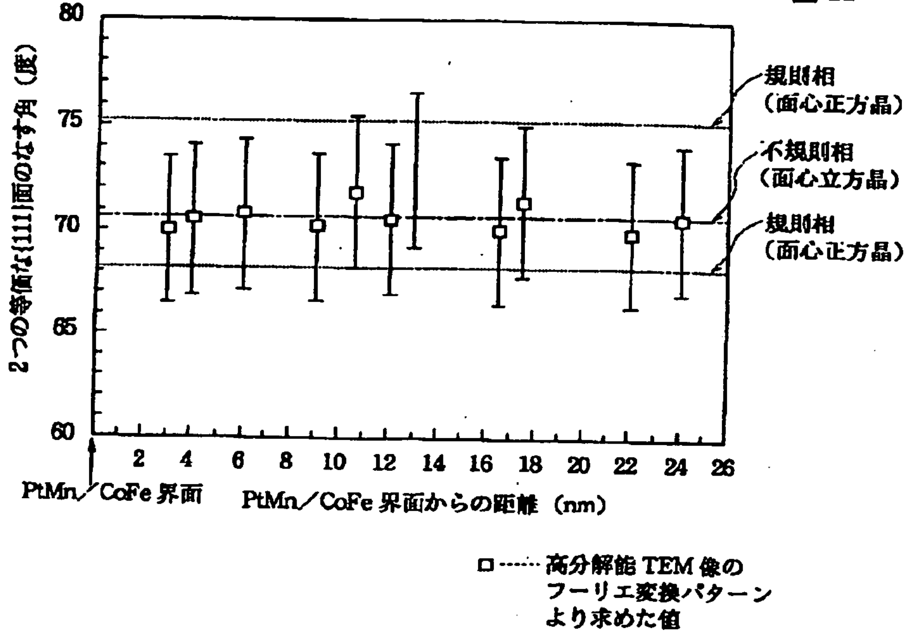
図8

【図9】

図9

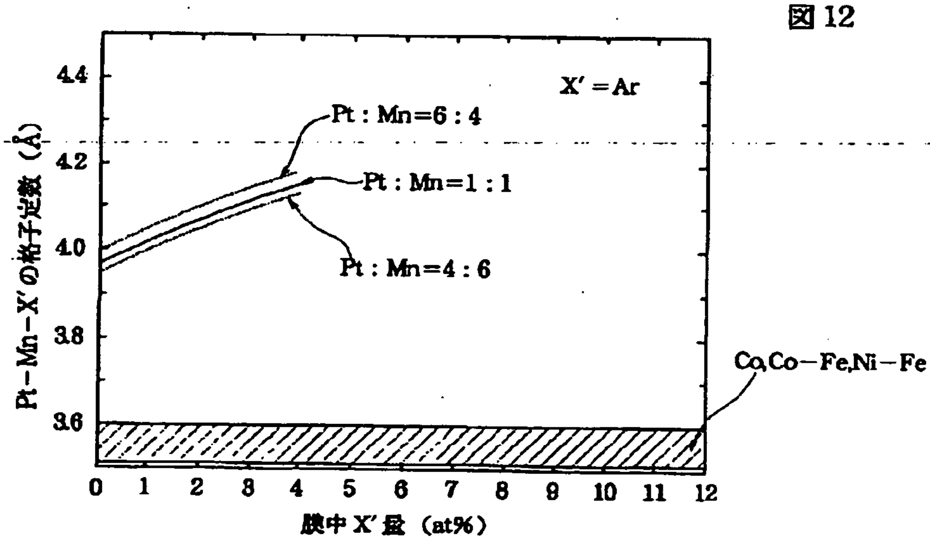
【図１１】

図 11



【図１２】

図 12



【図13】

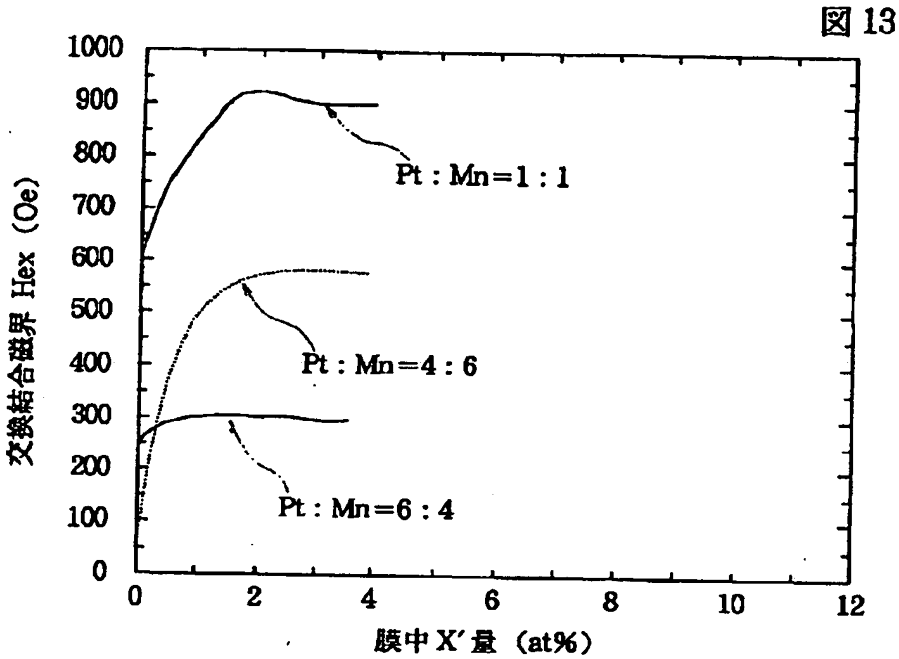


図 13
交換結合磁界 Hex (Oe)
1000
900
800
700
600
500
400
300
200
100
0
Pt : Mn=1 : 1
Pt : Mn=4 : 6
Pt : Mn=6 : 4
0
2
4
6
8
10
12
膜中 X′量 (at%)

【図14】

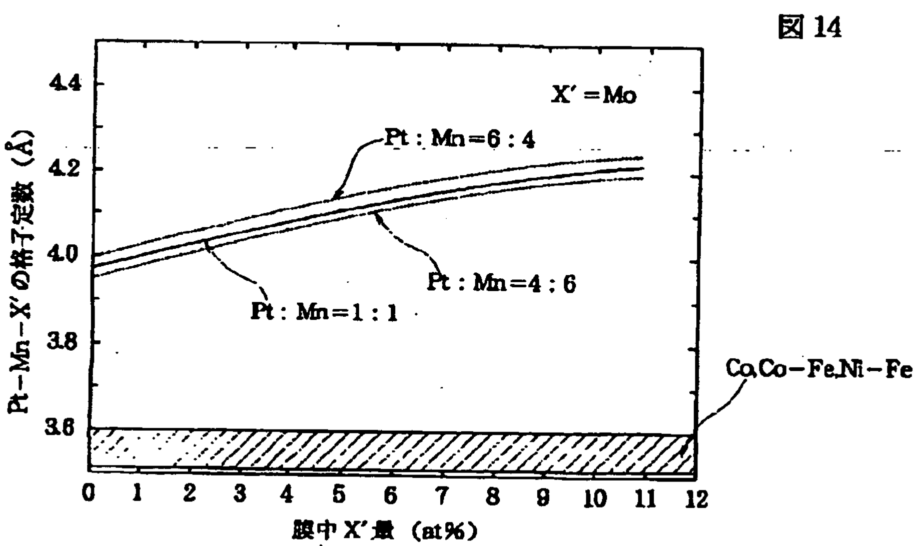
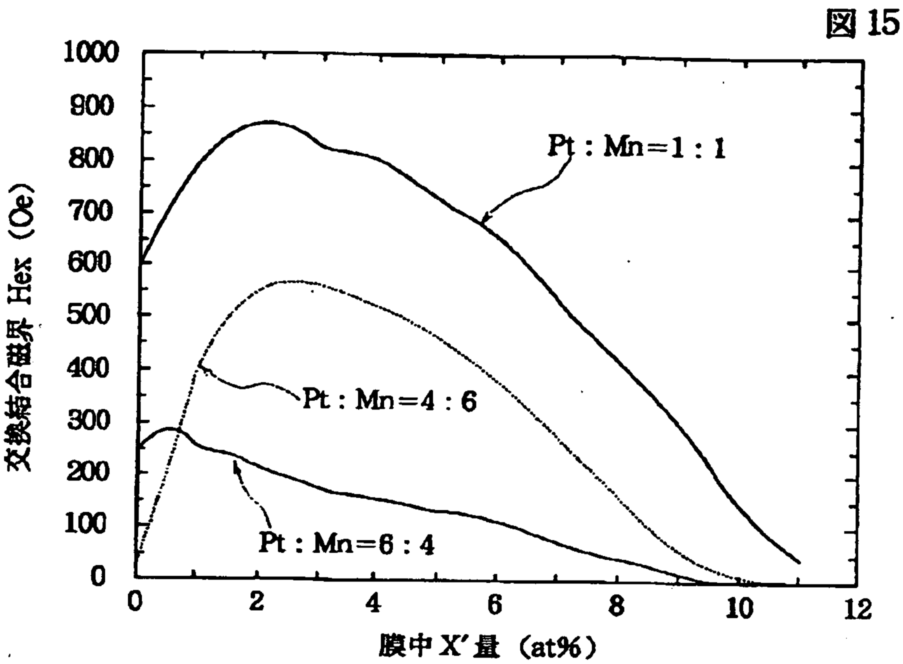


図 14
Pt−Mn−X′の格子定数 (Å)
4.4
4.2
4.0
3.8
3.6
X′=Mo
Pt : Mn=6 : 4
Pt : Mn=4 : 6
Pt : Mn=1 : 1
Co,Co−Fe,Ni−Fe
0 1 2 3 4 5 6 7 8 9 10 11 12
膜中 X′量 (at%)

【図15】



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